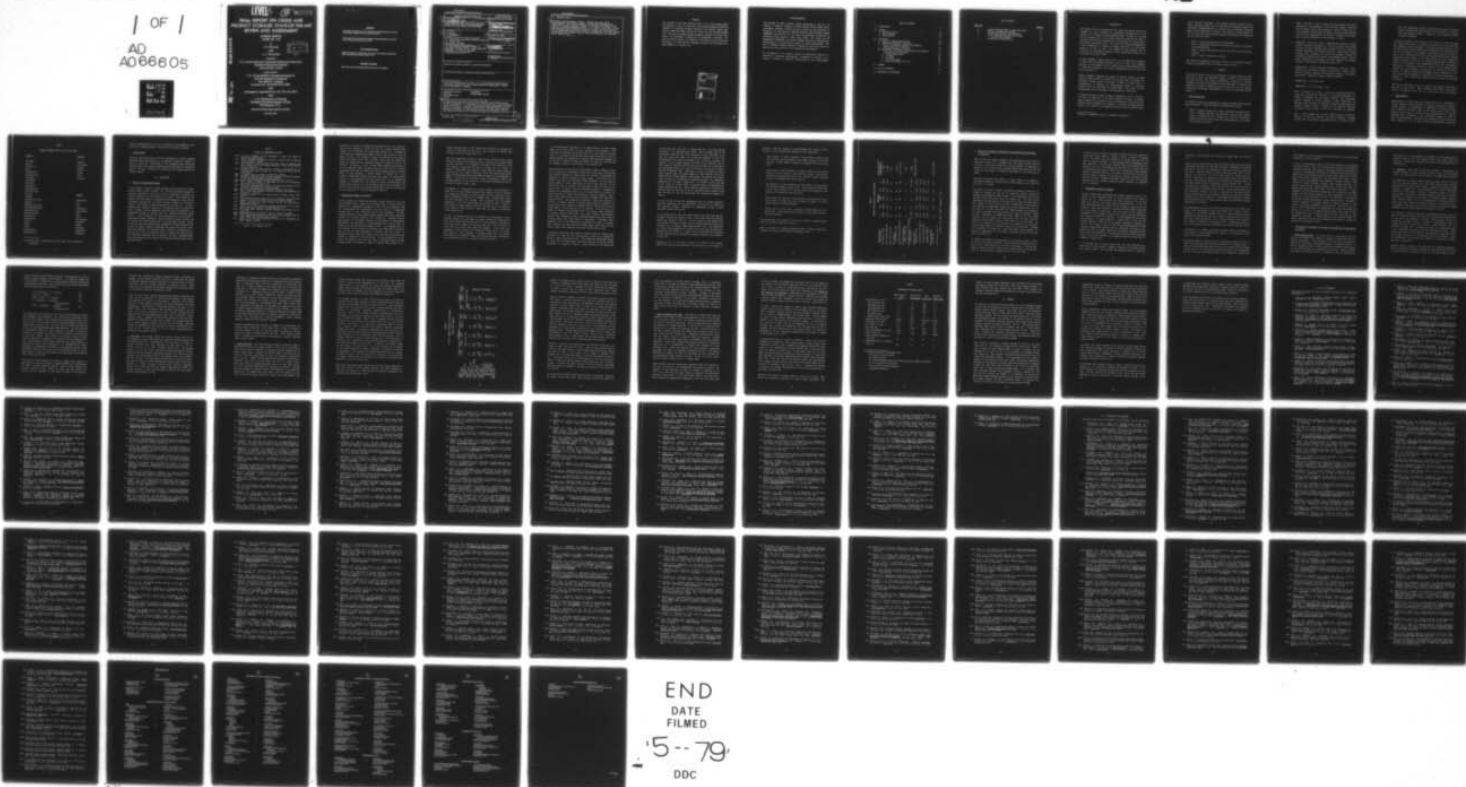


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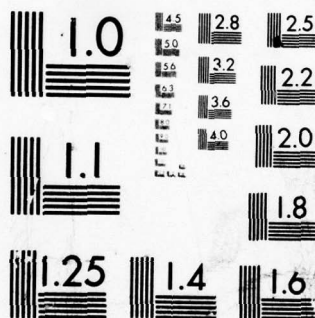
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FINAL REPORT ON CRUDE AND PRODUCT STORAGE: STATE-OF-THE-ART REVIEW AND ASSESSMENT

INTERIM REPORT
AFLRL No. 110

By

J.N. Bowden

and

L.L. Stavinoha

Prepared By

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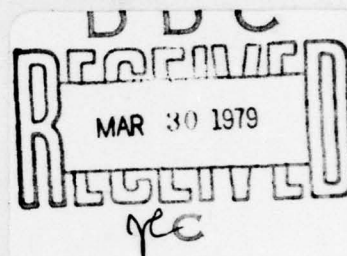
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20. ABSTRACT (cont.)


petroleum crude and product storage. Through literature review, questionnaires, and personal contacts, considerable information was identified for use in programs relating to the effect of storage on the quality of finished petroleum products. As a result of this task, it has been determined that underground storage of refined distillate products can be accomplished with proper selection of products to be stored, through specification requirements, quality control/surveillance, and judicious use of additives. ←

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FOREWORD

This document is the final report for Task 1 of a 4-task program, which was conducted at the U.S. Army Fuels and Lubricants Research Laboratory (USAFRLRL) at Southwest Research Institute, San Antonio, Texas under Contract DAAK70-78-C-0001, during the period June 1978 through November 1978. The work was funded through Interagency Agreement EL-78-A-01-2815 between the Department of Energy and the Department of Defense. The contract monitor was Mr. F.W. Schaekel of the Energy and Water Resources Laboratory, U.S. Army Mobility Equipment Research and Development Command, DRDME-GL, Ft. Belvoir, VA.

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The cooperation of the numerous persons who generously supplied information by answering questionnaires, responding to letters, or replying to questions at personal consultations is also acknowledged.

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I. INTRODUCTION

The Energy Policy and Conservation Act, which was signed into law on December 22, 1975, provided the legislative authorization for the creation of a Strategic Petroleum Reserve (SPR). The SPR is to provide for the storage of up to one billion barrels of petroleum in order to diminish United States vulnerability to the effects of a severe petroleum supply interruption (1)*. On May 25, 1977, SPR Plan Amendment No. 1 was transmitted to Congress as Energy Action No. 12, and became effective on June 20, 1977. The purpose of this amendment was to accelerate the development schedule to have 500 million barrels of oil in storage by the end of 1980.

A second amendment, Energy Action DOE No. 2, was submitted to Congress in April 1978 and became effective on June 13, 1978. This amendment provides for the expansion of the reserve size from 500 million barrels to 1,000 million barrels, and provides implementation for the third 250 million barrels (2).

Neither amendment considers the question of whether regional petroleum product storage should be provided for the East Coast or whether non-contiguous storage should be provided in Hawaii or Puerto Rico. A re-examination of regional and noncontiguous storage is presently underway within the Department of Energy (DOE). The results of this re-examination will be reported to the Congress at a later date.

If regional petroleum product storage is implemented, it will be imperative that the stability of the stored products be known. An investigative program was initiated to develop information to help ensure that products being considered for storage in a regional petroleum reserve would be of a quality to be immediately usable, and to identify likely

* Numbers in parenthesis refer to references in Section V.

quality assurance procedures. This program commenced through an inter-agency agreement between the U.S. Army Mobility Equipment Research and Development Command/Department of Defense and the Strategic Petroleum Reserve Office/Department of Energy. The program is being conducted at the U.S. Army Fuels and Lubricants Research Laboratory, and consists of the following four tasks:

- o Task 1 - State-of-the-Art Review and Assessment
- o Task 2 - Experimental study of the effect of storage on the quality of finished products
- o Task 3 - Update and expand data base for crude oil characteristic programs
- o Task 4 - Overall assessment and report.

This document encompasses the results of Task 1 on the "State-of-the-Art Review and Assessment" and is the final report for Task 1.

II. APPROACH

The state-of-the-art review and assessment of storage effects on crude and product quality was undertaken through: a search of the literature utilizing selected data bases; questionnaires submitted to various companies and foreign organizations having experience in long-term and underground storage of petroleum products and crude oil; and consultations with individuals knowledgeable in the area of petroleum storage stability.

A. Data Base Sources

A literature search was undertaken by computer accessing eight selected data base sources. These data bases are described as follows:

- o APILIT - Coverage dating back to 1964 of worldwide petroleum literature, including refining, petrochemicals, air and water conservation, transportation and storage, and petroleum substitutes. Prepared by Central Abstracting and Indexing Service of the American Petroleum Institute.

- o TULSA - From 1961 to date - Covers: petroleum geology, exploration geophysics, and geochemistry; well drilling, logging, completion and servicing; oil and gas production, reservoir studies and recovery methods; pollution and alternative fuels and energy sources; and petroleum transportation and storage. Prepared by the Information Services Department of the University of Tulsa.
- o ENERGYLINE - From 1971 to date - Comprehensive coverage of energy-related literature comprising over 200 core journals and selected coverage of several thousand other journals as well as reports and surveys, monographs, and newspaper articles. Subject-area coverage includes energy economics, U.S. policy and planning, research and development, resources and reserves, environmental impact, electric power transmission and storage, and fuel transport and storage. Prepared by Environmental Information Center, Inc.
- o CONDENS/CASIA - Chemical Abstracts Condensates - 1970-1971 - Bibliographic data and keyword phrases covering bio-, organic, macromolecular, applied, physical and analytical chemistry, and chemical engineering. Prepared by Chemical Abstracts Service.
- o CONDENS/CASIA - 1972-1976. Idem.
- o CONDENS/CASIA - 1977 to present. Idem.
- o NTIS - Retrospective to 1964 - A broad and cross-disciplinary file containing citations and abstracts of government-sponsored research, development and engineering reports; other government analyses prepared by federal agencies or their contractors and grantees; some reprints; and federally sponsored translations and foreign language reports. Prepared by the National Technical Information Service (NTIS) of the U.S. Department of Commerce.
- o SSIE - covers ongoing and recently completed basic and applied research in the life, physical, and social sciences. Coverage includes over 1300 funding organizations such as federal, state,

and local government nonprofit associations; colleges and universities; nonaffiliated investigators; and some non-U.S. organizations and private industry. Prepared by the Smithsonian Science Information Exchange.

A key-word hierarchy, shown in Table 1, was utilized to search the eight data bases listed above. It should be pointed out that the SSIE data base yielded no useful references. The other data bases yielded a total of 1400 citations, 300 of which were considered to be directly applicable to the stability and storage of petroleum product and crude oil. Many of these references were trade journal notices and short articles announcing various phases of the SPR program and other underground storage activities, and were not considered sufficiently technical in nature to be included in the alphabetized (Section VI) bibliography. References to underground storage of natural gas and gaseous hydrocarbons were quite numerous but also were not included in the bibliography. In addition, several environmental impact statements for various sites being considered for inclusion in the SPR program were referenced in some of these data bases, but were not used in preparing this report.

The List of References, Section V, contains the material referenced in the text of this report. These references also appear in the alphabetical bibliography where they are starred for cross referencing.

B. Questionnaires

Questionnaires of three types were prepared and sent to individuals in various companies having experience in storage of crude oil, storage of refined products, or manufacture of additives for refined products. Seven companies (including three in the United States, two in West Germany, and one each in Finland and The Netherlands) were contacted regarding their experience in the underground storage of crude oil and/or refined products. Responses were received from six of the seven. Eight companies in the U.S. were contacted regarding their experience

TABLE 1

KEYWORD HIERARCHY USED IN DATA BASE SEARCH

<u>Group A</u>	<u>Group B</u>
Petroleum	Storage
Gas oil	Containment
Gas(w)* oil	Storing
Crude	Reserve
Diesel(w) fuel	Stored
Diesel(w) fuels	Cache
Jet(w) fuel	Reservoir
Jet(w) fuels	
Fuel(w) oil	
Fuel(w) oils	
Turbine(w) fuel	
Turbine(w) fuels	
Kerosene	<u>Group C</u>
LP(w) gas	
Liquid(w) petroleum	Underground
Gasoline	Dome
Middle(w) distillate	Cave
Middle(w) distillates	Long(w) term
Residual(w) fuel	Short(w) term
Residual(w) fuels	Tank
Burner(w) oil	Tanks
Burner(w) oils	Subterranean
Jet(w) A	Stability
JP(w) 4	Stable
JP(w) 5	Oxidation
Burner(w) fuel	Degradation
Burner(w) fuels	Strategic

* (w) Words used in conjunction with each other only, and may be hyphenated.

and/or recommendations in the use of additives for increasing the storage life of refined products. Only three of the eight responded.

C. Consultations

Personal consultations were held with individuals in several companies regarding their experiences in the underground storage of refined products or crude oil. Individuals in two companies which manufacture additives were also contacted regarding their experience and recommendations in the use of additives for improving the storage stability of refined products.

III. DISCUSSION

A. History of Underground Storage

A chronological listing of events pertaining to the history of underground storage is shown in Table 2 (3). The term underground storage is generally understood to mean the storing of materials or products in unlined openings below the surface of the earth. These materials and products have been mainly of petroleum and petrochemical nature, and the underground openings may be either naturally existent or artificially created. The naturally existent openings are the gas-, oil-, or water-bearing porous spaces or fissures of sedimentary rocks or natural caverns. Storage in porous medium has found the widest application in the underground storage of natural gas and liquified petroleum gases (LPG's). These formations are either depleted gas or oil fields or water-bearing sands (aquifers). The artificially created cavities can be divided into either mechanically or solution-mined caverns. Layers of rock salt and salt domes are most suitable for solution mining as the caverns are easily created by injecting fresh water into the salt formation and removing the resulting brine. Mining by blasting and excavating can be done in nearly all types of stable rock, such as granite, limestone, sandstone, shale, anhydrite, and salt. Abandoned mines and unused tunnels may be converted into storage facilities under favorable conditions.

TABLE 2

HISTORY OF UNDERGROUND STORAGE

1909	The U.S. Geological Survey recommends to store the excess of natural gas underground.
1915	First successful underground storing of natural gas in Welland County, Ontario, Canada.
1916	Gas injection in the depleted Zoar field, south of Buffalo, New York, marked the first storage operation in the United States; still in operation.
1916	Deutsche Erdol AG (DEA) obtains a patent, covering the use of solution-mined salt cavities for the storage of crude oil and distillates.
1940	In Sweden first oil storage in mined rock caverns.
1941	Storage in combination oil and gas reservoirs was first developed by Hope Natural Gas Company in West Virginia.
1943	Start of LPG-underground storage (Carter Oil Co., U.S.A.).
1946	First aquifer storages of Muldraugh and Doe Run in Kentucky (Louisville Gas & Electric Co.).
1950	First solution-mined salt cavity for propane and butane put into operation at Keystonefield, Western Texas.
1951	More than 100 underground gas storage fields in the U.S.A.
1952	First large-scale aquifer storage at Herscher Dome (Natural Gas Storage Co., Illinois).
1954	Ethylene storage in a salt cavern starts at Fannet, Texas (Gulf Oil Co.).
1954	First successful gas storage in an oil reservoir (Lone Star Gas Company in its New York City field in Clay County, Texas).
1956	Dowell introduces the Sonar Caliper Log for the measuring of underground cavities.
1961	First use of salt caverns for storing natural gas in St. Clair County, Michigan (Southeastern Michigan Gas Co.).
1963	Old Leyden mine, Denver, Colorado, delivers stored gas for the first time.
1969	Abandoned mine in South Africa used for crude oil storage.
1969	First large-scale storage of crude oil in salt caverns starts in Europe (NWKG, Germany and Geosel, France).
1974	Start up of the first underground project for compressed air (NWK, Hamburg, Germany).

Source: B.O. Haudan, 1977 (3)

Depending on the type of underground storage facility, the stored products can be gaseous or liquid, and even the normally gaseous hydrocarbons can be liquified and stored under pressure (3). Although the first successful underground storage of natural gas occurred in 1915, as shown in Table 2, the storage of liquid oil products did not begin in mined rock caverns until 1940 in Sweden. Since 1966 the Federal Republic of Germany has had compulsory storage of imported crude oil and products. By January 1, 1975, a 90-day supply capacity was required of all oil companies, which included crude oil as well as fuel. Similar requirements now apply to France and other European Community countries where, in some instances, a 120-day supply is required (4). Until recently, underground storage has been used mainly for hydrocarbons. However, a new application has been found which is the underground storage of compressed air for combustion during peak-shaving at gas turbine power stations (3). The listing in Table 2 can be brought up to date with the creation of the United States SPR in 1975 and the increase of the storage goal to 1 billion barrels in 1978 (2).

B. Underground Storage of Crude Oil

In West Germany, the regulation governing minimum reserves of oil products brought about a search for economical ways of storing crude and products (4). Underground storage was known to be an economical route for accomplishing this requirement, and the creation of underground storage space in salt formations was the most economical. The geological formations in the northern German coastal region were especially suitable for solution mining of salt caverns (5). Numerous articles have appeared in the German literature on the subject of construction, maintenance, and operation of solution-mined salt caverns used for storage of crude and petroleum products (6-16). It is reported that, in West Germany, 64 salt caverns in different salt domes held 9.8 million tons of crude oil and distillates in storage at the end of 1976. An additional 13 were ready for filling at that time and 37 more were being leached or planned for solution mining. It was estimated that by the end of the seventies, the total salt dome oil storage capacity in West Germany would be increased to about 35 million cubic meters (3). A

former potassium mine in West Germany was converted for storage utilization by Winterhall AG and has a total capacity of 600,000 cubic meters of crude oil storage space (17).

The first large-scale storage of crude in salt caverns started in West Germany in 1969, but no monitoring of the condition of the stored crudes has been reported. It is estimated that some of the crude oil in the salt caverns at Lesum may have been in storage for 7 to 8 years. A project to investigate the condition of both crude and product stored at Lesum, as well as a similar facility at Etzel, has recently been undertaken by Kavernen Bau-und Betriebs-GMBH of Germany for the Department of Energy. A search of the literature revealed no systematic study of the storage stability of the crude oil, so the above investigation will be the first attempt at such a study.

In response to a questionnaire on crude storage, a representative of Mobil Oil AG in West Germany indicated that crude oils that are destined for storage are selected for low pour point and other qualities (letter from H. Rodenbusch of Mobil AG, 14 December 1977). Arabian light crudes are used extensively for storage. Mobil indicated that the maximum temperature in the salt dome caverns was estimated at 40°C. Filling of the crude oil storage caverns started 10 years ago, and it is planned to store crudes for about 20 years. Mobil does not monitor the condition of the stored crude.

In 1967, the Manosque project (85 kilometers north-northeast of Marseilles) started in France where 34 single caverns with capacities of 250 to 260 thousand cubic meters each for a total capacity of 10 million cubic meters were created by solution mining (18). Most of these caverns have been filled with crude and products. Fresh water displacement of these caverns will eventually enlarge them to 14 million cubic meters of total capacity. A storage project for 2.52 million cubic meters of petroleum in mined rock caverns was under construction in the Paris basin in 1977 at a depth of about 150 meters.

In the Scandinavian countries, it is common practice to mine storage space out of solid rock, as salt formations are nonexistent. This technique was developed during World War II for bomb shelter installations. Oil storage in rock caverns became important during the last two decades because the Scandinavian countries were completely dependent on oil imports. Finland, Norway, and Sweden all have vast installations for storage of crude oil and products in rock caverns (3).

Mined caverns were first used for hydrocarbon storage in Sweden in 1940, and the capacity of Scandinavian countries for this type of storage has been greatly expanded in recent years (3). Certain prerequisites are necessary to ensure successful storage, namely: the product must be lighter than water and relatively water insoluble; the rock must be strong enough to allow construction of fairly large caverns; and the water table must be constant and sufficiently above the level of the cavern floor to ensure a positive hydrostatic gradient. Consequently, ground water continuously seeps into the cavern where the products are stored and must be removed by continuous or periodic pumping. Thus, a bed of water exists more or less continuously beneath the stored hydrocarbons (19-22). The temperatures reported in these rock caverns are 10°-15°C. In Sweden, Arabian or Iranian light crudes are specified for storage, and Libyan crudes are sometimes used for mixing with lower pour point crudes. A pour point of -5°C is required (trip report by J.N. Bowden of USAFLRL, 23-24 November 1977.) In Finland, crudes identified as Tuymazy, Ekofisk, Agha Jari, Gach Saran, Basrah, Piper-Claymore, Arabian light, Safaniya, Kirkuk, and Hassi Messaoud have been used for storage (letter from Tuomo Saarni of Finncavern, 4 September 1978). Apparently in all the Scandinavian countries the crude oil storage, until recently, has been used for refinery supply rather than for strategic storage so the turnover time period is less than one year.

A practical method has been devised in South Africa for storing large quantities of crude oil for long periods to assure its availability during a supply interruption (23). This method is underground storage in worked out coal mines which have been converted to provide storage equivalent to a sizable oil field. A mine utilized in this manner was

in operation from June 1937 to January 1962 as a coal mine and was developed by the room-and-pillar method. After thorough study of the surrounding formations and after hydrostatic tests, conversion of the mine for storage was begun, and filling was completed in 1969 (23). Correspondence with Fenix and Scisson, Inc., of Tulsa, Oklahoma, developers of this storage program for South Africa, indicated that in 1976, crude oil had been stored in above ground tanks for 9 years and in the underground mines for 6.5 years (letter from S.E. Scisson of Fenix & Scisson, 29 November 1976). The types of crude in storage are Iranian light, Arabian light, and lesser amounts of other Mid-East crude oils. Crudes such as Iranian medium, Iranian heavy, and Cabinda have viscosities too high to be considered for long-term storage. The underground temperature in the mines is about 20°C. It has been reported that none of the crude oil stored either in surface tanks or underground has become unsuitable for use. Some evidence of emulsions at the oil-water interface has been observed as well as anaerobic bacteria growth at the same interface in both the above-ground and underground storage facilities.

In Great Britain the need for underground crude oil storage capability has been recognized, and the feasibility for this type of storage has been explored; however, apparently no underground storage is being practiced at this time (3, 24).

In the United States, the first solution-mined salt cavity was used for storage of propane and butane in 1950. A salt cavern was first used for natural gas storage in 1961 (3). In 1975 a survey of salt deposits and salt caverns and their relevance to the strategic petroleum reserve was conducted for the Federal Energy Administration (25). The feasibility of storing large quantities of crude oil in salt dome solution-mined cavities was the subject of a report to the 4th International Symposium on Salt sponsored by the North Ohio Geological Society, held in Houston in 1973 (26).

Immediately prior to and since creation of the SPR in 1975, several reports and articles have appeared in the literature on the subject of

strategic crude oil storage in solution-mined salt caverns (27-36). Initially, five sites have been obtained for SPR development:

- o Bayou Choctaw, 12 miles southwest of Baton Rouge, Louisiana with four existing cavities having a total usable volume of 36 million barrels. Allied Chemical Company has produced brine here since 1934.
- o Bryan Mound, 3 miles southwest of Freeport, Texas with 60 million barrels of usable volume in four existing cavities. Dow Chemical Company has operated brine wells here. The site could be expanded to store an additional 200 million barrels.
- o West Hackberry, 12 miles southwest of Lake Charles, Louisiana where Olin Chemical Company produces brine. Five existing cavities have a total usable volume of 57 million barrels with expansion room possible for another 160 million barrels.
- o Weeks Island, 95 miles west of New Orleans, Louisiana where Morton Salt Company has mined rock salt for nearly 75 years. Its total usable volume is 75 million barrels.
- o Sulphur Mines, 2 miles west of Sulphur, Louisiana where PPG produces brine. Three existing cavities have a total usable volume of 22 million barrels.

The eventual goal for storage of crude oil in these and possibly other sites is one billion barrels of crude oil.

Table 3 contains the purchase specification for 5 types of crude oils intended for storage in the domes at the present time.

TABLE 3

CURRENT SPR CRUDE OIL SPECIFICATIONS

Characteristic	I	SPR Type			V	Appropriate ASTM Test Method
		II	III	IV		
API Gravity (°API)	30-36	40-45	30-36	34-40	36-40	D 1298
Total Sulfur (wt%) max	1.99	0.25	0.50	0.25	0.50	D 1552
Pour Point (°F) max	50	50	50	50	50	D 97
Salt Content, (lb/1000 Bbl) max	50	50	50	50	50	D 3230
Viscosity (SUS @ 60°F) max	150	150	150	150	150	D 445 & D 2161
Reid Vapor Pressure (psig @ 100°F) max	11	11	11	11	11	D 323
Mercaptans (ppm in 375°-500°F fraction) max	No limit	12	12	12	No limit	D 1323
Yields (vol%) Naphtha (375°F)	24-30	35-42	21-29	29-36	30-38	D 2802 and/or D 1160
Distillate (375°-620°F)	17-31	21-35	23-37	31-45	19-33	
Gas Oil (620°-1050°F)	26-38	20-34	28-42	20-34	23-37	
Residuum (1050°F)	10-19	4-9	7-14	0-5	7-14	
Water and Sediment (vol%) max	1.0	1.0	1.0	1.0	1.0	D 96 or D 1796

Source: H.N. Giles - SPRO - December 7, 1978

C. Effects of Storage on the Physical and Chemical Characteristics of Crude Oil

Mobil AG reported through response to the questionnaire (letter from H. Rodenbush of Mobil AG, 14 December 1977) that some of their crude oil had been in salt dome storage for 10 years; however, no inspection or testing of the crude has been conducted during this period so that any changes in the chemical or physical properties of this crude are unknown.

Reference has already been made to a project which is in progress to investigate changes to crudes stored in West Germany in salt dome cavities for 7 to 8 years.

The crude oil stored in Sweden in mined-rock caverns is generally intended for refinery use and not for long-term storage. During the building and preparing of these caverns, it was anticipated that certain problems could arise with crude oil storage (19). The caverns were constructed with provisions for heating the oil and/or the water bed so that removal of the oil from the cavern storage would be made easier. The heating is accomplished through circulation systems where the oil, the water, or, in some cases both, are pumped through heat exchangers. Two special problems were anticipated with crude oil storage: sludge and gas. Experience in Sweden has shown, however, that the sludge formation has not caused the difficulties that had been expected. Caverns are made deeper to give a water bed of 2 to 3 feet deep. The crude oil is pumped in at one end and out the other end of the cavern, and any sludge formed is allowed to settle into the water bed. Although an accumulation of sludge over long terms might cause problems, the amount of sludge after 5 to 10 years of operation has proven less than had been feared (19).

To minimize the escape of gas and avoid loss of storage volume, a number of caverns are connected together so that gas can be transferred from a cavern with a high pressure to one with low pressure. It is also possible to connect caverns to above ground storage tanks if these exist. Crude oil is stored under a pressure of 0.5 to 2.5 bar (19).

In South Africa the effect of storage on crude oil has been reported to be minimal (letter from S.E. Scisson of Fenix & Scisson, 29 November 1976). The stored crude has apparently not become unsuitable for use over the period of storage. In both aboveground and underground storage, emulsions at the oil-water interface have been observed which are difficult to break. The emulsions are believed to be caused by action of centrifugal pumps used to remove water accumulated through seepage. Growth of anaerobic bacteria at the water interface has also been observed; however, formation of H_2S was not reported. Settling of heavy ends has occurred. Mixing of different types of crude in one storage location has been avoided, especially where paraffinic and asphaltic oils are concerned.

D. Underground Storage of Products

In West Germany eight underground gas storage reservoirs were in operation in 1977 containing about 1.7 billion standard cubic meters of natural gas (3). Other projects were under construction at the time. These are referred to as porous media storage projects. In 1971 the first solution-mined salt cavern for gas storage in Germany was constructed. Since then a number of projects have been under construction for the storage of natural gas. One salt cavern in West Germany is designated for the storage of butane, and others have been constructed for ethylene and other LPG products. An old potassium mine was sealed and connected to the gas network of a nearby town to serve as a gas storage reservoir. Many of the salt domes constructed in Germany are used for the storage of gas oil under the government-mandated storage reserves program which requires that an equivalent of 90 days of consumption be kept in storage. Based on the properties indicated by Mobil AG as being representative of the materials stored in their salt dome caverns, the gas oil referred to in Germany appears to be very close to a ASTM No. 2 burner fuel.

It is reported that in France, natural gas, LPG, and distillates are stored in salt dome caverns. Propane is reported to be stored in mined rock caverns (3,18). An iron mine 200 kilometers west of Paris was

converted to five million cubic meters of storage space for fuel oil (3).

Several sources indicated that gases and other products have been stored underground in Russia for some time (3,37,38). Underground gas storage started in 1954, and this consisted of injection of gas into a depleted gas field. Aquifer storage of natural gas near large cities is extensive. In 1972 over 14 billion cubic meters of natural gas were stored. Plans exist for expansion of old storage fields and creation of new ones in aquifers and depleted zones near Moscow, Leningrad, Kiev, in the Urals, North Caucasus, Transcaucus, and West Ukraine (3). In 1964 the leaching of a large salt cavern was started, and two cavities are in operation near the Armenian capital Erevan. Haudan concluded that many LPG underground storage sites are in operation in the Soviet Union, based on reports found in the Russian literature on practical problems associated with LPG storage (3). Development and operation of underground storage sites for various products have been reported by Russian investigators (37,38,39).

The Scandinavian countries have been storing gasoline, jet, diesel, and burner fuels underground in mined rock caverns for a number of years. Personnel at the Swedish National Board of Economic Defense verbally reported that gasoline and jet fuels stored in rock caverns for 15 years have been tested and found to be in a "new" condition (trip report by J.N. Bowden of USAFLRL, 23-24 November 1977). Underground storage of fuel oil and butane in Finland and Norway has also been reported (3,40).

In response to an inquiry concerning long-term storage of products in South Africa, it was indicated that there is no experience in that country with product storage.

Underground storage of natural gas was initiated in Canada in 1915 (3). Since then, many reservoirs have been used there for storage of gas. A number of salt caverns have been in operation in Canada also for storage of gas and LPG. In Great Britain certain companies have investigated the use of old coal and anhydrite mines for gas storage but learned that

the fissures in the overlying rock and fracturing of the roof were poor conditions for this storage (3).

A report on underground storage for petroleum presented to the National Petroleum Council in 1957 (41) indicates that liquid petroleum products (liquified petroleum gases being the principal one) have been stored in a variety of underground facilities in the United States for many years. These include salt-solution cavities in salt domes, mined salt cavities, mined rock caverns, depleted oil and gas sands, water sands, stratigraphic traps, and abandoned slate quarries. Products stored in these facilities include ethylene, propane, butane-propane mixtures, isobutane, normal butane, normal isobutane mix, olefin feed stock, liquified petroleum gas, LPG blends, and natural gasoline. A report prepared by the Gas Processors Association (42) states that the underground salt dome storage capacity for light hydrocarbons in the United States was 354 million barrels in 1977. The majority of this capacity is devoted to light hydrocarbons as listed above; however, a category of "others" comprised 54.5 million barrels of capacity reported in some cases to be gasoline, condensate, and diesel fuel. Therefore, the storage of light hydrocarbons in underground salt domes and bedded salt deposits is not new to the United States; however, the storage of heavier hydrocarbons such as diesel fuels and burner fuels has not been extensively practiced. A growing number of U.S. chemical process industry companies are finding that underground facilities for storage are practical and economical (43,44).

E. The Effects of Storage on the Physical and Chemical Characteristics of Products

1. Gaseous Hydrocarbons. As stated earlier in this report, the literature was examined with respect to storage of natural gas and other gaseous hydrocarbons. Those references that were studied indicate no instability attributed to underground storage of natural gas and LPG. A need to dehydrate certain of these products on withdrawal from cavities to meet specifications was indicated in some cases. Butane, propane, and lighter hydrocarbons stored in depleted oil and gas sands and in

water sands or in stratigraphic traps generally are contaminated with residual crude oil and its dissolved gases, light gases, and water. Products so stored and contaminated may require reprocessing prior to marketing (41).

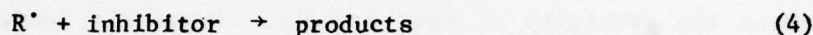
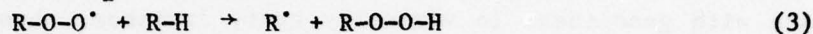
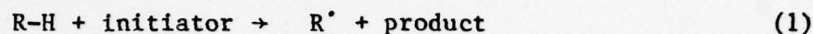
2. Gasolines. When crude oil was first refined by distillation, the various fractions, used as different types of fuels, were relatively stable, and autoxidation of these products in storage was not observed.

The demand for the fraction known as gasoline brought about the development of refinery processes, one of the first being thermal cracking. The gasoline from this process tended to oxidize and deteriorate rather rapidly in storage (45). The rearranging of the heavier hydrocarbon molecules by this process produces a considerable amount of olefins, some of which are unstable. Processes developed later such as catalytic cracking also produce a certain amount of unstable olefinic components (46). Earlier studies (45) of the composition of petroleum fuels revealed that they contain not only hydrocarbons of paraffinic, cyclic, and aromatic nature but also sulfur-, nitrogen- and oxygen-containing compounds which are deleterious to the quality of the fuel.

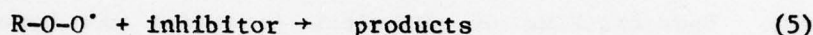
The stability of gasoline has been investigated extensively from the aspect of long-term storage and in terms of oxidation and polymerization in the tank of the vehicle to form gum. The military's interest in stockpiling gasolines prompted a number of investigations into the storage stability of these fuels (47-51). Similar studies have been conducted in Canada (52). In Russia the effect of underground storage on the properties of gasoline has been investigated (53-55). These studies have shown that, in general, the stability of gasolines varies with composition and can be improved with the use of additives. Japanese investigators have studied gum formation in catalytically cracked gasoline in storage (56).

Unstable gasoline, exposed to the action of air at ambient temperature while in storage, will undergo oxidation and some polymerization to form a resinous material referred to as gum. In the early stages of form-

ation, this material may remain in solution in the gasoline, but, due to further chemical change, will precipitate. It is generally agreed that the autoxidation of gasoline is a chain reaction involving peroxide and hydrocarbon-free radicals. The reactions that occur during autoxidation can be characterized as follows (45):



(nondeleterious)



(nondeleterious)

The second and third reactions tend to be self-perpetuating and therefore propagate the autoxidation. The inhibitors or antioxidants react with the free radicals, thus stopping the self-propagating chain reaction as shown in the fourth and fifth reactions generally resulting in nondeleterious products (45). The most effective inhibitors have been found to be phenylenediamines and hindered phenols. The chain-breaking or terminating function of these additives is thought to proceed by donation of a hydrogen atom from the reactive center of the antioxidant to the peroxy radical. The activity of the peroxy radical is sufficiently stabilized by resonance to discontinue chain propagation (57, 58). Certain metals, notably copper, dissolve, even though slightly, in gasoline and become active catalysts in the decomposition of hydroperoxides, thus supplying free radicals to the oxidation process. Metal deactivator additives will react with the dissolved copper as well as other metals to form a stable chelate, thus destroying the pro-oxidant effect of the metals (58).

Most gasoline specifications have tests to indicate the condition of gasoline at the time of the test; for example, ASTM D 381 (existent gum) and ASTM D 525-IP40 (induction period), which is also accepted as a stability predictive test. During the 1960's and early 1970's, extensive work was conducted by the Bureau of Mines in Bartlesville,

Oklahoma (now Bartlesville Energy Technology Center, Department of Energy), and by Stanford Research Institute, to investigate the nature of gasoline oxidation products generated in storage and also to develop predictive tests for storage stability of gasolines (59-61). Other tests have been developed and advanced as predictive tests with respect to the oxidative stability of gasolines (62-64).

Since the late 1950's, numerous processing and composition changes have taken place with gasolines. In virtually every instance, these changes have improved the stability of this product. Presently, very unstable thermally cracked gasoline components and polymer gasolines are almost nonexistent. Hydrocracking of petroleum fractions was begun in the middle 1940's, and the practice has increased considerably over the years. This process, reforming, and other refinery processes produce gasolines that are considerably more stable than the thermally cracked gasoline (45,57). Exhaustive hydrotreating removes not only all olefin material by saturation but also sulfur, oxygen, and nitrogen compounds. Due to these improved processes and the use of additives, long-term storage of gasolines has been practiced in Russia, Scandinavian countries, and, to a limited extent, in the U.S. with no significant deterioration of the product (53,54).

3. Jet Fuels. The storage stability of aircraft turbine fuels or jet fuels has been for some time defined and controlled through existent and accelerated gum tests. Investigations into the effect of storage on various properties have been conducted for many years in the U.S (65-73), as well as in other countries (52,74,75,76). The storage stability of jet fuel is well controlled through the extensive refining needed to meet the stringent requirements placed on jet fuels by various military and civilian specifications, and through the use of antioxidant additives (77,78). The high-temperature stability of aircraft jet fuels has been the subject of many investigations because these fuels may be subjected to thermal stresses arising during sustained supersonic flights and in some high-altitude subsonic applications (79-90). The storage stability of these high-temperature fuels has been the subject of other investigations (91-97).

Resistance to oxidation and polymerization at the operating temperatures encountered in certain jet aircraft is an important performance requirement. In high-speed flight, the fuel is subjected to considerable heat input due to kinetic heating of the airplane and also to the use of the bulk fuel as a coolant for engine oil, hydraulic, and air conditioning equipment, etc. Consequently the fuel must be able to perform at temperatures up to 250°C without formation of lacquer and deposits which can adversely affect the efficiency of the heat exchangers, metering devices, fuel filters, and injector nozzles. Research on the problem led to the development of the ASTM-CRC Fuel Coker (ASTM D 1660), which is a laboratory test apparatus for measuring the tendency of jet fuels to deposit thermal decomposition products in fuel systems. A new test for Thermal Oxidation Stability of Aviation Turbine Fuels (JTOT), ASTM D 3241, which requires only 600 ml of sample as opposed to 6 gallons for the Fuel Coker, and takes only 2.5 hours as opposed to 5 hours, is being generally accepted for specification purposes.

Russian investigators have reported no changes in the properties (including thermal stability) of jet fuels, after 5 years of storage in rock salt caverns at 26°C, nor did the amount of sodium in the fuel exceed that found in freshly refined fuel (98). Other Russian studies show an increase in gum precursors and decrease in thermal stability after 3 years (76,99).

4. Distillate Fuels. The term "distillate fuels" is generally taken to mean fuels boiling in the range of 350° to 750°F, but is restricted to those that are used for domestic and industrial heating purposes and for diesel engine fuels. Although the boiling ranges of kerosene and jet fuels are all within these limits, they are not classified as distillate fuel oils (45). Higher boiling materials are generally classified as industrial fuel oils and called heavy fuel oils or residual fuels. Before the advent of cracking processes, and up to about 1946, distillate fuels consisted predominantly of straight run products. Although they were subject to oxidative attack, their stability on the whole was adequate for the demands placed upon them. With the increase in catalytic cracking and greater demand for diesel fuel, both thermal- and

catalytic-cracked stocks have been used in distillate fuels, which has greatly increased their susceptibility to oxidation. The oxidative attack results in the formation of soluble and insoluble materials of higher molecular weight and boiling point than the original fuel. This insoluble gum (or sediment) can cause plugging of filters, screens, and nozzles in both diesel and burner installations (45,100,101).

The storage stability of middle distillates has been the subject of numerous field storage programs in which the determination of the storage life of these fuels was the main object (102-111). Some fundamental studies led to the discovery that certain nitrogen compounds that may be present in distillates contribute significantly to sedimentation (112-114). Many of the storage stability investigations led to the development of accelerated stability and predictive tests for the storage of distillate fuels. ASTM D 2274 is perhaps the most accepted procedure for this purpose in the United States, but it is still surrounded by controversy. For this method, a measured volume of filtered fuel is aged at 95°C for 16 hours while oxygen is bubbled continuously through the sample. It should be recognized that any correlation between this test and field storage may vary significantly under different field conditions or with distillates from different sources. Work on storage stability of fuels in Great Britain led to the development of stability tests described in the British Ministry of Defense Specification DEF, Methods 16 and 17 (111). In Method 17 the sample is aged for four weeks in an oven at 49°C. It is then filtered, and the weight of the residue plus gum or lacquer remaining in the bottle is reported as milligrams of total sediment per hundred milliliters of fuel. Method 16 "ages" the fuel at 99°C for 16 hours in darkness but with sufficient air supply. These tests are reported to be of value in predicting the behavior of fuels in storage (111).

Many other methods have been proposed and are used by some companies to ensure the quality of their product (115-118). One study conducted by the Navy and reported in 1958 utilized 26 different procedures for predicting storage stability (120).

TABLE 4

GAS OIL SAMPLES FROM SALT DOME STORAGE
in
LESUM, WEST GERMANY

Cavern Sample Date Approximate Storage Time Remarks	Compulsory				Seasonal		
	L-104 11/9/73	L-104 1/31/74	L-104 9/74	L-104 1/23/75	L-106 9/75	L-106 4/28/76	L-106 11/77
	Since June 1973				Since September 1975		
Color, ASTM	0.5	0.5	0.5	0.5	Blanket	L1.0	
Stability, D 2274, mg/100 ml	0.5	0.4	0.5	0.8	1.3	1.0	
Neutr. No., mg KOH/g	0.06	0.08	0.06	0.06	0.06	0.11	
Spec. grav., g/ml @ 20°C	0.833	0.834	0.833	0.833	0.834	0.836	
Sulfur, wt%	0.28	0.25	---	0.39	---	---	
Cloud Point, °C	-8	-7	-7	-7	-7	-6	
Distillation, °C							Testing in Progress
10% recovered	200	197	205	200	204	210	
50% recovered	---	249	258	255	256	264	
95% recovered	343	335	342	343	---	346	
85% recovered	---	---	---	---	---	318	
Flash Point, °C	60	---	73	67	314	75	
Sodium, ppm	---	---	---	---	53	---	
					0.12	---	

Russian investigators have reported that two similar diesel fuels that differed in naphthene content and acidity were stored for over 40 months in contact with brine. Analyses after the storage period showed an increase in acidity with no change in other properties (121). Other Russian investigators reported no effect under similar conditions (122).

Special refinery treatment of thermal- and catalytic-cracked stocks has been found to improve distillate fuel stability (123,124) and use of antioxidant, metal deactivator, and dispersant additives also improves stability (125-128) (letter from C.P. Henry of E.I. duPont de Nemours & Company, 8 September 1978; letter from J.D. Bartleson of Ethyl Corp., 23 August 1978). One company especially interested in long-term fuel storage intended for use in emergency standby generating equipment recommends the use of a dispersant containing a metal deactivator (but not anti-oxidants) as the most effective stabilizing additive package for diesel fuels. Fuel shelf life up to 20 years is claimed (129) (letter from G.H. Kitchen of Bell Labs, 2 March 1978). This experience was also addressed in a recent report on switching of fuel oils during a national emergency (130). Federal Specification VV-F-800B, Fuel Oil, Diesel, and MIL-F-16884-F, Fuel Oil, Diesel, Marine, contain lists of approved anti-oxidants for use in these fuels, and the marine diesel fuel specification also contains a list of approved metal deactivators.

Reviews of stability and deterioration of distillate fuels were published in 1966 (131) and 1977 (132). Mobil AG has monitored gas oil stored in salt dome caverns in West Germany since 1973, and the results are shown in Table 4 (trip report by J.N. Bowden of USAFLRL, 23-34 November 1977). The materials appear to have the same boiling range as a No. 2 distillate fuel, and no deterioration of the fuel is apparent based on these data (D2274 values, sodium levels and lack of particulates). A German firm under contract to DOE is currently performing detailed analyses on samples of the gas oil from one of the Lesum salt dome caverns.

If a water-fuel interface exists when the fuel is in storage, bacterial and fungal activity may occur. This activity has been the subject of

many investigations involving surface storage, and it is generally agreed that it can best be arrested by good housekeeping practices, such as ensuring a minimum water bottom in the storage container (133-138). Certain biocidal additives have been found to be effective in controlling microbiological activity (139-141). Storage of distillate fuels over brine may tend to reduce microbiological growth (trip report by L.L. Stavinoha of USAFLRL, 21 July 1978). Biological activity has not been observed in the salt dome storage projects; however, anaerobic bacterial activity was suspected in the mine storage of crude oil in South Africa (letter from S.E. Scisson of Fenix & Scisson, 24 November 1976).

5. Heavy or Residual Fuel Oils. Instability in residual fuel oils may manifest itself either as waxy sludge deposited at the bottom and sides of an unheated storage tank or as fouling of preheaters while heating the fuel to elevated temperatures. There is much speculation regarding the mechanism of sludge deposition. It may be due to oxidation, polymerization, or the method of producing the fuel. Whichever process is involved, insoluble compounds are formed which eventually settle to the tank bottom and form sludge (142). Asphaltene deposition may result from the mixing of fuels of different origin and treatment. Straight run fuels from the same crude source are normally stable and mutually compatible. Heavy fuels produced from thermal cracking and visbreaking operations can be incompatible if blended with straight run fuels. Blending of No. 2 fuels with residual fuel from cracking or visbreaking processes may result in asphaltene precipitation (143). The general mechanism of sediment formation in distillates has been reviewed (45) and sedimentation rates calculated for No. 4 vs. No. 6 fuel oils (letter from B.L. Mickel of Amoco Oil Co., 17 August 1978).

Light residual oils may contain waxy components which will separate if the fuel is stored at cool temperatures for extensive periods. The presence of waxy materials can have ill effects on handling of the fuels, thus cloud and pour point limits are generally specified when purchasing these fuels. It has been found, however, that these tests fail to predict the pumpability temperature of the fuel (143) after some

period of storage, and pumpability testing has been a major concern of the industry and the British Admiralty since the early fifties (144). As a result, a number of investigations into this problem were conducted, and several technical reports were published in the Journal of the Institute of Petroleum, culminating in the development of a pumpability method designated IP 230/69 (145-154). ASTM has also developed a method, ASTM D 3245, designed to give the minimum cold storage and minimum handling temperatures which may be used for a given fuel oil.

In 1960 a construction company in Sweden began building underground storage caverns in rock formations for oil companies and for the governments of Sweden, Finland, France, and other European countries (letter from S. Bylund of SENTAB/Svenska, 25 September 1978). Various designs are used for these caverns, depending on the material to be stored and whether or not the facility is for refinery storage. If the storage is for crude oil or heavy fuel oil and especially if it is for reserve storage, then a system for heating the oil, the water bed, or both is designed into the construction of the storage cavern. To facilitate withdrawal of the oil, the storage temperature in these types of caverns is maintained at 50° to 60°C.

A hydrotreated-vacuum oil similar to ASTM No. 4 burner fuel has been proposed as a candidate for the regional product storage program under consideration by DOE. Table 5 compares the suggested properties of this product to the requirements for marine diesel fuel, a navy distillate fuel, and ASTM No. 4 burner fuel. In the middle 1960's the U.S. Navy began converting selected steam-boiler ships to the use of a distillate fuel described by Military Specification MIL-F-24397, Navy Distillate (ND) (108). This fuel (the use of which has since been discontinued) was a higher boiling material than diesel fuel marine (DFM) and approached the viscosity range of a No. 4 fuel. A program was conducted to evaluate the storage characteristics of four fuels meeting the requirements of the ND fuel.

The fuels were stored in columns, bottles, and cans for 3 years. This period was considered indicative of field storage experience. The

TABLE 5

PROPERTIES OF VARIOUS FUELS

	SPRO Proposed <u>Fuel*</u>	Diesel Fuel <u>Marine(DFM)</u>	Navy <u>Distillate</u>	ASTM No. 4 <u>Burner Fuel</u>
Distillation, D 86, °F				
10% Distilled, max	---	---	500	---
50% Distilled, max	---	---	644	---
90% Distilled, max	---	675	740	---
95% Distilled, max	---	---	765	---
End Point, max	---	725	---	---
Residue plus loss, % max	---	3.0	---	---
Viscosity, SUS at 100°F	45-125	31-41	58.9 max	45-125
Flash Point, °F, min	130	140	150	130
Pour Point, °F, max	20	20	25	20
Ash, wt%, max	0.10	0.005	0.01	0.10
Water and Sediment, v %, max	0.50	---	0.02	0.50
Sulfur, wt%, max	0.30	1.00	1.30	legal
Carbon Residue, Ramsbottom,				
wt%, max	0.3	0.2	0.4	---
Compatibility with a standard fuel oil	yes	---	---	---

* Possible additional requirements are:

20 v% max of cracked stocks

no residual stocks

10 to 20 pound/thousand barrels (PTB) amine type oxidation inhibitor

0.5 total PTB metal deactivator

0.5 total PTB corrosion inhibitor

a dispersant additive

results of these storage experiments were correlated with accelerated experiments using ASTM D 2274 and a 110°F oven storage procedure. It was concluded from this program that the ASTM D 2274 procedure was probably a suitable method for predicting the storage characteristics of the navy distillate fuel.

IV. SUMMARY

The practice of storing petroleum products and crude underground began in 1915 with the successful storing of natural gas in old gas wells in Welland County, Ontario, Canada. Since then, two types of underground storage have been used in various parts of the world. These are porous media and cavities. The porous media include depleted gas or oil fields and waterbearing sands, also referred to as aquifers, and are utilized primarily for storage of gaseous materials such as natural gas, butane, propane, butylene, ethylene, propylene, and air. The cavities may be abandoned mines, mined cavities in granite, rock salt or other suitable rock formations and in solution-mined cavities in salt. Liquid products, including LPG, gasoline, distillates and crude oil, have been stored in salt cavities and in mined cavities, and abandoned mines have been used for crude oil and distillate storage.

Until recently, long-term, strategic storage of crude oil has taken place only in a few instances in Europe and in South Africa. Based on what is known for this limited number of cases, it appears that the refinability of crude oil will not be affected by prolonged storage. Most crudes will likely deposit a "sludge" during storage which may interfere with withdrawal pumping. It is speculated that this sludge is composed of microcrystalline wax, sand, water, and possibly asphaltenes. Emulsions at the water-oil interface have been reported after prolonged storage and these have been attributed to the action of centrifugal pumps used to remove accumulated seepage water. It is possible that these emulsions resulted from biological activity, although the only such activity reported was thought to be anaerobic (a process that generally produces hydrogen sulfide), but no detection of H_2S was noted. The bitumen sediment and water inherently present in crude may contribute to this layer by settling out during quiescent storage.

Underground storage of products, including natural gas, LPG, gasoline, diesel fuel, burner fuel, gas oil, and jet fuel has become common practice in Europe. The lighter products, natural gas through gasoline, and, in a few instances, diesel fuel have been stored in salt cavities and mines in this country for varying periods of time since about 1943. There are no reports of deterioration, although these are mostly short-term storage programs (one year or less) as opposed to long-term reserve storage programs.

Several governments, notably West Germany, France, and other European Community countries, have imposed regulations that reserves of products must be kept by various oil companies to ensure against petroleum shortages. Salt dome cavities and mined rock caverns are typically utilized for this product storage, and even though storage temperatures range from a low of approximately 5°C in mined rock caverns to a high of 50°C in some of the salt dome caverns, none of the stored products was reported to be unstable even after a number of years. One instance of a relatively high sodium content in a gas oil (equivalent to a No. 2 fuel oil) stored in West Germany was observed. However, by blending with a fresh refinery product at a 2 to 1 ratio, this fuel was utilized with no further problem.

In general, the reports reviewed and the personal contacts made indicate that long-term underground storage of refined distillate products has been accomplished with proper selection of products to be stored, through specification requirements, quality control/surveillance, and judicious use of additives to control any potential oxidation, sediment formation, biological activity, etc.

No experience with extended storage of heavy or residual fuels has been reported in the literature, although correspondence related to this study indicates the Scandinavian countries have had experience in this area. The main concern with storage of this fuel is wax and sludge separation, which is controlled by continuous dynamic heating of the fuel.

A program has been initiated in West Germany, under a contract between KBB GmbH and the Department of Energy, to sample and analyze crude oil and product stored in two different salt domes. Results of this effort are not yet available but will be informative when completed.

While considerable information was gained on the prolonged storage of crude oils and products, no specific guidelines were identified for purchase specifications, quality control/surveillance, and for handling of jet or heavy burner fuels. Considerable information was identified for use in programs relating to the effect of storage on the quality of these finished products.

V. LIST OF REFERENCES

(These same references are also contained in the Section VI, Alphabetical Bibliography.)

1. _____, Strategic Petroleum Reserve Annual Report, February 16, 1978, DOE/RA-0004/1 (77).
2. _____, Strategic Petroleum Reserve Plan, Expansion of the Strategic Petroleum Reserve, Amendment No. 2, Energy Action DOE No. 1, March 1978, DOE/RA-0032/2, UC-13.
3. Haudan, B.O., Worldwide Underground Storage, Oil Gas Europe Mag, V. 3, N. 1, pp 36-38, 41-47, Apr 1977.
4. Lambrich, K.H., Kuehns, G., Experiences Gained in the Creation and Operation of Caverns in Salt Domes with a Large Content of Impurities, Proceedings of the Ninth World Petroleum Congress, V. 5, pp 81-88, 1975.
5. Hagemann, E., Germans Look to Salt Domes to Ease Oil Storage Problems, World Petrol., V. 40, N. 6, pp 26-27, Jun 1969.
6. Hofrichter, E., Storage of Energy Fuels in Salt Caverns... Geological and Mineralogical Problems, Erdoel Ergas Z, V. 88, N. 8, pp 284-94, Aug 1972, Pet Abstr, V. 12, N. 52, ABSTR No. 168 136, Dec 23, 1972.
7. Lechler, S., Experience Gained in the Construction and Operation of Lesum Cavern Storage, Erdoel Erdgas Z, V. 90, N. 3, pp 80-87, Mar 1974 (In German).
8. Lechler, S., Here's How Mobil Prepares Storage Caverns in German Salt-Domes, Petrol Petrochem Int, V. 11, N. 12, pp 64-68, 73, 80C, Dec 1971.
9. Dreyer, W.E., Results of Recent Studies on the Stability of Crude Oil and Gas Storage in Salt Caverns, Northern Ohio Geol. Soc., Proceedings of the 4th Int Salt Symp, V. 2, pp 65-92, 1974.
10. Grodde, K.H., Process for Detecting an Interface Between Two Media, Especially Between Oil and Brine in the Construction and Operation of Storage Caverns, Ger 2,363,783, C 2/13/75, F 12/21/73.
11. Rischmuller, H., Salt Caverns for the Storage of Crude Oil and Natural Gas in West Germany. A General Discussion of the Technical and Economic Aspects, Erdoel Erdgas Z, V. 88, N. 7, pp 240-248, Jul 1972 (In German).
12. Roehr, H.U., Factors Influencing the Leaching of an Underground Storage Reservoir in a Salt Dome in View of Obtaining Information for Planning and Control Operations, Erdoel Kohle, Erdgas, Petrochem, V. 22, N. 11, pp 670-9, 1969 (In German).

13. Ruhl, W., Large Scale Underground Storage of Gaseous and Liquid Hydrocarbons, Erdoel Kohle, Erdgas, Petrochem, V. 24, N. 5, pp 299-309, May 1971 (In German).
14. Schmidt, K., Technical and Economical Aspects of Leaching of Oil and Gas Storage Caverns at the EPE Salt Mines, Haus Tech Meet (Essen 6/3-4/75) Tech Mitt, V. 68, N. 9-10, pp 363-68, Sept-Oct 1975 (In German).
15. Wilke, H., Legal Foundations of Underground Storage, Erdoel Erdgas Z, V. 83, N. 7, pp 246-253, Jul 1967 (In German).
16. Gomm, H., Hieblinger, J., Kuehn, G., German Caverns Store 60-Million-bbl Oil Reserve, Oil Gas J, V. 76, N. 27, pp 60-64, Jul 3, 1978, and V. 76, N. 28, pp 153-158, Jul 10, 1978.
17. _____, Wintershall A.G.'s Underground Storage Completed, Pet Times, V. 77, N. 1973, p 13, Nov 16, 1973.
18. DuBois, D., Maury, V., Underground Storage of Hydrocarbons at Manosque, France, Northern Ohio Geol Soc, Proceedings of the 4th Int. Salt Symp Prod, V. 2, pp 313-321, 1974.
19. Jansson, G., Rock-Cavern-Type Storage Can Be Cheaper Option, Oil Gas J., V. 72, N. 43, pp 74-76, 79-82, Oct 28, 1974.
20. Orvell, G., Drilling Caverns for Underground Storage, Petroleum Engineer, V. 49, N. 6, p 70, Jun 1977.
21. Christenson, K.R., Nilsson, S.O., Crude and Product Storage in Man-Made Caverns, Pipe Line Ind, V. 41, N. 6, pp 40-43, Dec 1974.
22. Christenson, K.R., Oil Storage Underground: The Principles of Storage, Petrol. Rev, V. 24, N. 286, pp 320-322, Oct 1970.
23. Brandt, H.W., Abandoned Coal Mine Converted into Man-Made Oil Field, Fenix & Scisson International Inc., Oil Gas J., V. 70, N. 52, pp 76-78, Dec 25, 1972.
24. Weeks, J.P., Smith, R., Underground Fuel Storage, Petroleum Review, pp 767-773, Nov 1975.
25. Jirik, C.J., Weaver, L.K., A Survey of Salt Deposits and Salt Caverns--Their Relevance to the Strategic Petroleum Reserve, US Federal Energy Adm Rep No. FEA/S-76/310, 72 pp, July 1975, PB-225, 948/2GA (A0).
26. Von Schonfeldt, H., Corcoran, A.E., Jessen, F.W., Feasibility of Storage of Large Quantities of Crude Oil in Salt Dome Solution Cavities, North Ohio Geol Soc, Proceedings of the 4th Int Salt Symp V. 2, 227-83, 1974, Pet Abstr V. 15, N. 12, Abstr No. 202 437 Mar 22, 1975.
27. Read, W., LOOP Plans Salt-Dome Crude Storage, Oil Gas J, V. 73, N. 30, pp 44-45, July 28, 1975.

28. Jackson, H.M., Morton, R.C.B., Ford Mulls Strategic-Storage System, Oil Gas J, V. 72, N. 48, p 34, Dec 2, 1974.
29. Hill, J., FEA (U.S. Federal Energy Adm) Unveils Early Storage Plant, Oil Gas J, V. 74, N. 17, p 78, Apr 25, 1976.
30. Cross, J.S., Emergency Crude Oil Storage Is Advocated, American Petroleum Institute, Oil Gas J, V. 73, N. 15, p 32, Apr 14, 1975.
31. Davies, R.L., FEA Eyes Potential Oil Storage Sites, Oil Gas J, V. 73, N. 47, pp 22-23, Nov 24, 1975.
32. Noel, T., Hill, J., Field Work (Is) Near for U.S. Strategic-Storage Plan, U.S. Federal Energy Adm, Oil Gas J, V. 74, N. 41, p 80, Oct 11, 1976.
33. Noel, T.E., Strategic Petroleum Reserve Program Will Require New Lines, Pipe Line Ind, V. 46, N. 5, pp 35-38, May 1977.
34. O'Donnell, J.P., Nine Brine Pits to Serve Underground Storage, Oil Gas J, V. 70, No. 38, pp 100-101, Sep 18, 1972.
35. Bachman, W.A., Crude to Flow to U.S. Strategic Storage, U.S. Federal Energy, Oil Gas J, V. 75, N. 21, pp 26-27, May 23, 1977
Chem Week, V. 170, N. 21, p 17, May 25, 1977.
36. Brown, D., Building a National Strategic Petroleum Reserve, Environ Data Serv, pp 10-12, Mar 1977.
37. Solovjev, A.N., Filinov, M.V., Kiselev, A.I., "Theoretical Fundamentals of Calculations and Results of Operation of the Semi-Commercial Gatchiuskaja Underground Gas Storage", Ninth World Petroleum Congress Proceedings, V. 5, pp 109-114, 1975.
38. Isupov, Yu, G., Khaziev, N.N., Abakumov, V.A., Exploitation of an Underground Storage Reservoir for Oil Products, Formed in Salt Formations, Neft Knoz, V. 44, N. 10, pp 61-64, Oct 1966 (In Russian).
39. Andreeva, E.M., Chernikin, V.I., Thermal Interference in a Series of Underground Storage Cavities, IZV Vysshikh Uchebn Zavedenii Neft I Gaz, V. 8, N. 3, 85-89, 1965.
40. Windolf, G., Sweden's Underground Millions, Tunnels and Tunnelling, pp. 24-26, Sep 1976.
41. Burns, H.S.M., Underground Storage for Petroleum--A report on the industry's experience with underground storage for petroleum products. Presented by the Committee on Underground Storage for Petroleum to the National Petroleum Council, Mar 7, 1957.
42. _____, North American Storage Capacity for Light Hydrocarbons, 1977, Gas Processors Association.

43. Serata, S., Use of Salt Cavities for Storage of Gas and Fluid Fuels in the Energy Crisis, Amer Soc Min Eng Annu Meet (Dallas Feb 23-28, 1974) Prepr No. 74-h-64, 14p, Pet Abstr, V. 15, N. 15, Abstr No. 203 465, Apr 12, 1975.
44. Weismantel, G.E., Underground Storage: Moving Closer to Real Paydirt, Chem Eng, V. 85, N. 2, pp 81-83, Jan 16, 1978.
45. Nixon, A.C., Autoxidation and Antioxidants of Petroleum, Ch. 17 in Autoxidation and Antioxidants, W.O. Lundberg, ed., V. II, Interscience, New York, 1962.
46. Boltd, K.A. and Griffith, S.T., Motor Gasoline and Vaporizing Oil, Ch. 5 in Criteria for Quality of Petroleum Products, J.P. Allison, ed., John Wiley & Sons, New York, 1973.
47. LePera, M.E., Investigation of the Autoxidation of Petroleum Fuels, U.S. Army Coating and Chemical Laboratory, Aberdeen Proving Ground, Rept No. CCL-204, 2p, Jun 1966, AD 641 270.
48. LePera, M.E., Investigating the Elastomer Environmental Effects on the Storage Stability of Military Fuels, U.S. Army Coating and Chemical Laboratories, Aberdeen Proving Grounds Rept No. CCL-279, 27p, Apr 1970, AD 704 707.
49. Bowden, J.N., Storage Stability of Federal Specification Gasolines, Southwest Research Inst., San Antonio, TX, Army Fuels and Lubricants Res. Lab., Rept. No. AFLRL-34, 20p, Jul 1974, AD 784 282.
50. Schwartz, F.G., Whisman, M.L., Albright, C.S., Ward, C.C., Storage Stability of Gasoline. Fundamentals of Gum Formation, Including a Discussion of Radiotracer Techniques, US Bureau of Mines Bull 626, 44p, 1964.
51. Albright, C.S., Whisman, M.L., Schwartz, F.G., The Use of Tritium Tracer Techniques in Studies of Gasoline Storage Stability, U.S. Bureau of Mines Rept Invest. N. 6373, 17p, 1964.
52. Strigner, P.L., Long Term Storage of Hydrocarbon Fuels in Coated Drums. Part III. Examination of Fuels After Five Years of Storage, National Research Council of Canada, Rept No. DME-MP-30, 26p, May 13, 1964, AD-678 478.
53. Azev, V.S., Kuznetsova, L.N., Stability of the Color of Ethylated Gasolines during Underground Storage, Transp Khranenie Nefti Nefteprod, N. 7, pp 28-29, 1975 (In Russian).
54. Azev, V.S., Kuznetsova, L.N., Marinchenki, N.I., Effect of Rock Salt and Brines on the Quality of Automotive Gasolines during Underground Storage, Transp Khranenie Nefti Nefteprod, N. 9, pp 20-23, 1974 (In Russian).

55. Azev, V.S., Kuznetsova, L.N., Malykhin, V.D., Marinchenko, N.I., Results of Tests of Automobile Gasolines by a Complex of Methods of Qualification Evaluation Following Their Long Time Storage in Salt Formations, Transport I Khranenie Nefteproduktov I Uglevodore. N. 2, pp 14, 1977 (In Russian).
56. Kanesaki, K., Takenouchi, Y, Gum Formation in Catalytically Cracked Gasoline on Storage, Sekiyu Gakkai Shi, H. 4, pp 238-42, 1962 (English Transl) Inter Chem Eng, V. 4, N. 1, pp 158-64, Jan 1964.
57. Bartleson, J.D., Shepherd, C.C., How to Select Gasoline Anti-oxidants, Hydrocarbon Process Petrol Refiner, V. 43, N. 8, pp 153-158, Aug 1964.
58. Polss, P., What Additives do for Gasoline, Hydrocarbon Processing, V. 52, N. 2, pp 61-68, Feb 1973.
59. Schwartz, F.G., Allbright, C.S., Ward, C.C., Storage Stability of Gasoline: Oven Test for Prediction of Gasoline Storage Stability, U.S. Bureau of Mines, Rept No. RI-7197, 32p, Dec 1968, AD-683 748.
60. Schwartz, F.G., Whisman, M.L., Allbright, C.S., Ward, C.C., Storage Stability of Gasoline. Development of a Stability Prediction Method and Studies of Gasoline Composition and Component Reactivity, U.S. Bureau of Mines, Bull N. 660, 64p, Sep 1972, PB-212 555.
61. Bassler, G.C., Smith, J.R., Fundamentals of Fuel Stability, Stanford Research Institute, Final Report for Department of the Army, 1961.
62. Kolobielski, M., Estimation of Dipole Moment of Oxidized Gasolines: A Potential Method for Evaluating Effectiveness of Additives, ACS Div Petrol Chem Preprints, V. 21, N. 4, Aug 1976.
63. Roels, R., Testing the Oxidation of Motor Fuel in the Presence of Copper, J Inst Petr, V. 50, N. 481, pp 22-26, Jan 1964.
64. Grupe, K.H., Malinka, H., Hentschel, G., Determining Motor Fuel Storability, Ger. (East), Patent 93972, Applic No. 150 761, Oct 20, 1970.
65. Cole, C.A., and Nixon, A.C., Stability of Jet Fuels in Storage, U.S. Air Force Technical Report No. 6625, Contract A.F. 33(038)-7277, Nov 1951.
66. Johnson, C.R., Fink, D.E., Nixon, A.C., Stability of Aircraft Turbine Fuels, Ind Eng Chem, V. 46, p. 2166, 1954.
67. Nixon, A.C., Cole, C.A., Minor, H.B., The Effects of Composition and Storage on Laboratory Properties of Jet Fuels, SAE Paper 524, Jun 1955.
68. Minor, H.B., Nixon, A.C., and Thorpe, R.E., Stability of Jet Turbine Fuels, U.S.A.F. WADC TR 53-63 (AD 118084#), Feb 1957. Part IV, USAF WADC TR 53-63 (AD 118085) Feb 1957.

69. Lander, H.R., Jr., Storage Behavior of High-Temperature Jet Fuels, Soc Auto Eng Mtg Paper N. 5391, SAE Journal V. 72, N. 9, p 189, Sep 1964.
70. Leas, A.M., Reclamation of JP-6 Type Jet Fuels Which Became Thermally Unstable During Storage, Contract: AF33 657 11097, 2p., Jun 1964, AD-601 984.
71. Lander, H.R., Jr., Stability of High-Temperature, Hydrocarbon Jet Fuels During Storage, Air Force Aero Propulsion Lab, Wright Patterson AFB, Rept No. APL-TDR-64-107, 2p., Nov 1964, AD-610 591.
72. Johnston, R.K., Anderson, E.L., A Review of Literature on Storage and Thermal Stability of Jet Fuels, U.S. Dept Com Office Tech Serv Publ, 30p., Jan 1964, (ABSTR) Mater Res Std, V. 4, N. 9, p 520, Sep 1964.
73. Johnston, R.K., Monita, C.M., Jet Fuel Stability and Effect of Fuel-System Materials, Southwest Research Institute Rep. No. SwRI-RS-515, 47p, Contract: AF-33(625)-2327, Feb 1968 AD-828 472/9ST.
74. Bol Shakov, G.F., The Effect of Gum Formed in the Storage of TS-1 Fuel on its Thermal Oxidation Resistance, Khim Tekhnol Topl Masel, V. 9, N. 1, pp 55-58, Jan 1964.
75. Malysheva, I.V., Melenteva, N.I., Study of the Thermal Stability of Jet Fuels Freshly Prepared and After Protracted Storage, Khim Tekhnol, Topl Masel, V. 13, N. 7, pp 46-47, 1968.
76. Ivanov, A.L., Romanov, A.N., Gladkikh, V.A., Kachurina, G.V., Alekseeva, M.P., Englin, B.A., Change in the Properties of Hydrogenated Fuels During Long-Term Storage, Khim Tekhnol Topl Masel, N. 5, pp 27-30, 1975, Chem Abstr, V. 83-149986 (in Russian).
77. Johnston, R.K., Improving the Storage Stability of Jet Fuels by the Use of Additives, Soc Automotive Engrs Mtg Paper N. 2393, (ABSTR) SAE Journal, V. 72, N. 9, p 189, Sep 1964.
78. Tumar, N.V., et al., Increasing the Chemical Stability of Jet Fuels with the Use of Antioxidant Additives, Khim Tekhnol Topl Masel 1976, 13; Chem Abstr 84, 16705n, 1976.
79. Bagnetto, L., Thermal Stability of Hydrocarbon Fuels, Phillips Petroleum Co., Bartlesville, OK, Research Dev. Rept No. 4559-66R, 2p, Sep 1966, AD-621 531.
80. Bagnetto, L., Thermal Stability of Hydrocarbon Fuels, Phillips Petroleum Co., Bartlesville, OK, 2p, 15 Aug 1965, Contract AF33 657 10639, USGRDR6521.
81. Bagnetto, L., Thermal Stability of Hydrocarbon Fuels, Phillips Petroleum Co., Bartlesville, OK, Research Div. Quarterly Progress Rept No. 4236-65R, 72p., 1 Jul-31 Aug 1965.

82. Bagnetto, L., Schirmer, R.M., Thermal Stability of Hydrocarbon Fuels, Phillips Petroleum Co., Bartlesville, OK. Research Div., Rept No. 4390-66R, 90p., 16 Mar 1966.
83. Kittredge, G.D., Thermal Stability of Hydrocarbon Fuels, Phillips Petroleum Co., Bartlesville, OK, Contract AF33(616)7241, 159p, Jul 63, PB-166 959.
84. Kittredge, G.D., Thermal Stability of Hydrocarbon Fuels, Contract AF33(626)7241, AD-285 636.
85. Kittredge, G.D., Streets, W.L., Ratchford, R., Thermal Stability of Hydrocarbon Fuels, U.S. Dept. of Com., Office Tech. Serv., 1961, AD 262 338.
86. Davydov, P.I., Bol'shakov, G.F., Glebovskaya, E.A., A Study of The Effect of Nitrogen Bases on the Stability of Fuels at High Temperatures, Khim Teknol Top Masel, V. 7, N. 10, 1962.
87. Englin, B.A., et al., Effect of Nitrogenous Bases on the Thermal Stability of Jet Fuels, Nefteperal Neftekhim, 1973, N. 3, pp. 9-11, Chem Abstr, V. 79, 44129j, 1973.
88. Taylor, W.F. and Frankenfeld, J.W., Development of High Stability Fuel, Final Report for Phase I, Naval Air Propulsion Test Center, Contract N00140-72-C-6892, Jan 1975.
89. Taylor, W.F., Frankenfeld, J.W., Development of High Stability Fuel, Rept No. EXXON/BRU.17.GAHF.76, Contract: N00140-74-C-0618, 88p, Dec 1976, AD-A038 977/5ST.
90. Taylor, W.F., Frankenfeld, J.W., Development of High Stability Fuel, Exxon Research and Engineering Co, Final Rept for Phase 2, Rept: EXXON/GRU.15GAHF.75, Contract: N00140-74-C-0618, 147p, Dec 1975, AD-A020 383/6ST.
91. Ward, C.C., Whisman, M.L., Goetzinger, J.W., Cotton, F.O., A Radio-tracer Study of Turbine Aircraft Fuel Stability, US Bureau of Mines Rep Invest No. 7493, 30p., Mar 1971.
92. Whisman, M.L., Goetzinger, J.W., Ward, C.C., Storage Stability of Aviation Turbine Fuels: A Radiotracer Technique for Estimating Component Contribution to Thermally Induced Deposits, U.S. Bureau of Mines, Rept No. RI7325, 28p, Dec 1969, AD-698 742.
93. Whisman, M.L., Goetzinger, J.W., Ward, C.C., Storage Stability of High Temperature Fuels. Part III. The Effect of Storage upon Thermally Induced Deposition of Selected Fuel Components and Additives, U.S. Bureau of Mines, Contract: F33615-57-M-5003, 95p, Jun 1970, AD-797 524.
94. Whisman, M.L., Ward, C.C., Storage Stability of High Temperature Fuels. Part II. The Effect of Storage upon Thermally Induced Deposition of Labeled Fuel Components, U.S. Bureau of Mines, Contract: F33615-67-M-5003, 127p, Mar 1969, AD-685 201.

95. Whisman, M.L., Ward, C.C., Storage Stability of High Temperature Fuels, U.S. Bureau of Mines, Contract: AF33 615 64 1009, 2p, Feb 1965.
96. Whisman, M.L., Ward, C.C., Storage Stability of High Temperature Fuels, U.S. Bureau of Mines, Contract AF-3048, Feb 1967, AD-647 787.
97. Whisman, M.L., Ward, C.C., Storage Stability of High Temperature Fuels. Part I. Micro Fuel Coker Tests of Fuel-Radiotracer Blends Before Storage, U.S. Bureau of Mines, Contract: F33615-67-M-5003, 103p, Mar 1968, AD-667 818.
98. Azev, V.S., Seregin, E.P., Gladkikh, V.A, Stryuk, N.V., Skurodin, G.B., Kuznetsova, L.N., Long-Term Storage of Jet Fuel T-1 in Underground Reservoirs Formed in Rock Salt Formations, Transp Khranenie Nefti Nefteprod, N. 4, pp. 19-22, 1976 (In Russian).
99. Sablina, Z.A., Gureev, A.A., Kikushkin, A.A., Melent'eva, N.I., Englin, B.A., Fomina, A.M., Changes in the High-Temperature Properties of Jet Fuels During Prolonged Storage, Khim Tekhnol Topl Masel, V. 15, N. 12, p 3942, 1970 (In Russian).
100. Offenhauer, R.D., Brennan, J.A., and Miller, R.C., Sediment Formation in Catalytically Cracked Distillate Fuel Oils, Ind Eng Chem, V. 49, p. 1265, 1957.
101. Greatorex, R., Lodwick, J.R., Some Aspects of the Filter-Clogging Properties of Middle Distillates, API Proceedings Div. Refining, V. 43, 1963.
102. _____, Distillate Fuel Storage Program, Summary Report No. 1, Western Petroleum Refineries Association, Tulsa, OK, 1956.
103. _____, Distillate Fuel Storage Program Summary Report No. 2, Western Petroleum Refineries Association, Tulsa, OK, 1958.
104. _____, Navy-CRC Barge Storage Program, Coordinating Research Council (CRC) Report, New York, Jul 1957.
105. Allbright, C.S., Schwartz, F.G., Ward, C.C., "Diesel Fuel Stability Testing," Project Serial No. SR-001-06-02 (BuShips), U.S. Bureau of Mines, Bartlesville Petroleum Res. Center, Bartlesville, OK, Oct 1966.
106. Elmquist, E.A., A Review of the Distillate Fuel Stability Program, ASTM STP No. 244 - Stability of Distillate Fuel Oils, Boston, Mass., Jun 1958.
107. Halliwell, H., Engine Test of Barge-Stored Diesel Fuels, U.S. Naval Engineering Experiment Station Report No. 620129A, Apr 1959.
108. Garner, M.Q., White, E.W., The Storage Stability of Navy Distillate Fuel for Ships, Naval Ship R&D Ctr, Report 4198, Apr 1974.

109. LePera, M.E., Sonnenburg, J.G., Storage Stability of Automotive Diesel Fuels, U.S. Army Coating Chemical Laboratory, Aberdeen Proving Ground, Rept No. CCL-315, 27p., Oct 1972, AD-752 906.
110. LePera, M.E., Sonnenburg, J.G., How Stable is Diesel in Storage, Hydrocarbon Process, V. 52, N. 9, pp 111-115, 1973.
111. Ritchie, J., A Study of the Stability of Some Distillate Diesel Fuels, J Inst Petr, V. 51, N. 501, Sep 1965.
112. Bentur, I., Babitz, A., Manor, P., Rocker, K.I., Storage Stability of Diesel Fuels, Israel Journal of Technology, V. 5, N. 3, 1967.
113. Oswald, A.A., Noel, R., Role in Pyrroles in Fuel Instability, J Chem Eng Data, V. 6, N. 2, p. 294 1961.
114. Houlihan, W.J.. Indoles, V. 25, Part I of Heterocyclic Compounds, Remers, W.A., and Brown, R.K., eds., Wiley and Sons, N.Y., 1972.
115. Allen, C.F.H., Young, D.M., and Gilbert, M.R., Indole Formation from Pyrroles, J Org Chem, V. 2, p. 235, 1937.
116. Vamos, E., Pataki, E., Storage Stability of Fuel Oils, Energi-agazdalkodas, V. 12, N. 7-8, pp 295-301, 1971 (In Hungarian).
117. Clinkenbeard, W.L., How Distillate Fuel Stability Is Measured and Controlled, ASTM STP No. 244 - Stability of Distillate Fuel Oils, Boston, Mass., Jun 1958.
118. Bertollette, W.D., Marvel, H.D., Survey of Roadside Diesel Fuel Filterability", ASTM Symposium of Diesel Fuels, Atlantic City, N.J., Jun 1966.
119. Gyrath, F.W., Dunn, F.R., Smith, A.C., One-Day Stability Tests for Distillate Fuel Oils, ACS Division of Petroleum Chemistry, Chicago Meeting, Sep 1958.
120. MacDonald, J.W., Jones, R.T., Predictive Type Tests for Storage Stability and Compatibility of Diesel Fuels, ASTM STP No. 244: Stability of Distillate Fuel Oils, Boston, Mass., June 1958.
121. Berezina, R.M., Gureev, A.A., Azev, V.S., Change in Diesel Fuel Quality During Long-Term Storage in Underground Cavities Prepared in Rock Salt Formations, Transp Khranenie Nefti Nefteprod, (1974) N. 2, pp 27-29, 1974, Chem Abstr, V. 81 52013 (In Russian).
122. Stryuk, N.V., Usacheva, E.V., Effect of Aqueous Media on the Chemical Stability of Fuels, Transp Khranenie Nefti Nefteprod, N. 5, pp 39-40, 1976 (In Russian).
123. Cherikov, Ya B., Gureev, A.A., Kuzmina, N.A., Kuzneisov, E.G., The Use of Thermal Cracking Kerosine Stabilized by Autoxidation as a Component of Diesel Fuels, Neftepererab I Neftekhim, N.5, pp 4-7, 1969.

124. Sirola, J., Utilization of Catalytically Cracked Distillates in the Production of Diesel Fuel, Nafta (Zagreb), V. 13, pp 398-404, 1962, (Abstr) J Inst Petr, V. 49, N. 479, p 231A, Nov 1963.
125. Miller, C.O., Arnold, A.P., Resume of Additives for Diesel Fuels and Their Function, SAE Mid-Year Meeting, Detroit, MI, 1970.
126. Gupta, S.D., Iyer, N.V., Pundir, B.P., Antioxidants for Fuels, Chem Age India, 1971, V. 22, N. 8, pp 524-527, Chem Abstr, V. 75, 131288.
127. Bertollette, W., Rogers, J.D., Improving Fuel Oils Through the Use of Additives, Petr Eng, p C41-C46, Nov 1956.
128. Kirchner, J.P., Osterhout, D.P., Schwinderman, W.R., Improvement of Distillate Fuels by Additive and Refining Techniques, ASME Paper No. 55-A-213, Annual Meeting Chicago, Nov 1955.
129. Kitchen, G.H., Fuel Storage Life, NPRA Technical Paper 66-14, San Antonio, Texas, Mar 1966.
130. Silla, H., Switching Fuel Oils During a National Emergency, Report prepared for the Strategic Petroleum Reserve Office, DOE, Stevens Institute of Technology, Dec 1977.
131. Ward, C.C., Schwartz, F.G., Review of Some of the Fundamentals of Hydrocarbon Storage Stability, Soc Auto Eng Mtg Paper No. 650936 (1965), SAE Trans, V. 74, Pt. 3, p. 983-992, 1966.
132. Stavinoha, L.L., LePera, M.E., A Review of Diesel Fuel Deterioration and Related Problems, Southwest Research Inst., San Antonio, TX, Army Fuels & Lubricants Res Lab, Rept No. AFLRL-88, 28 p, May 1977, AD A043566/9St.
133. Hendey, N.I., Some Observations on Cladosporium Resinae as Fuel Contaminant and Possible Role in Corrosion of Aluminum-Alloy Fuel Tanks, Trans Brit Mycological Soc, V. 47, N. 4, pp 467-75, 1964 (Abstr) Corrosion Abstr, V. 4, N. 5, p 345, Sep 1965.
134. Hill, E.C., Biological Problems of Fuel Storage, Chem Brit, V. 1, N. 5, p 190, May 1965.
135. Hazzard, G.F., The Detection of Micro-Organisms in Petroleum Products, J Inst Petr, V. 53, N. 524, pp 267-274, Aug 1967.
136. Roberts, G.A.H., Microbiological Corrosion of Tanks in Long-Term Storage of Gas Oil, Brit Corros J, V. 4, N. 6, pp 318-321, Nov 1969.
137. Footner, H.B., Roberts, G.A.H., Microbiological Corrosion of Tanks in Longterm Storage of Gas Oil, Brit Corros J, V. 5, N. 2, p 64, Mar 1970.
138. Roberts, G.A.H., Microbiological Corrosion of Tanks in Long-Term Storage of Gas Oil--2. Further Bacterial Studies and Use of Borax as a Biocide, Brit Corros J, V. 8, N. 2, pp 86-88, Mar 1973.

139. Hitzman, D.O., Linnard, R.E., Control of Microbial Growths in the Storage of Petroleum Fuels, Phillips Petroleum Co., 7th World Petrol Cong (Mexico City 4/2-8/67), Paper N. PD-36(2).
140. Klemme, D.E., Leonard, J.M., Inhibitors for Marine Sulfate-Reducing Bacteria in Shipboard Fuel Storage Tanks, Nav. Res. Lab., Washington D.C., U.S. Nat. Tech. Inform Serv., 22p., 1971, AD 730024.
141. Nagy, K.V., Pokoj, D.E., Navy Fuel Interactions with Additives. Phase I. An Investigation of Side Effects from a Commercial Biocide, U.S. Nat. Tech. Inform. Serv., 25p, 1975, AD-A018966.
142. Kite, W.H., Jr., Stephens, G.G., Fuel Oils, Including Domestic Heating Oils, Ch. 9 in Criteria for Quality of Petroleum Products, J.P. Allison, ed., John Wiley & Sons, New York, 1973.
143. Greatorex, R., Thermal Treatment of Light Residual Fuels to Minimize Wax Separation Problems, J Inst Petr, V. 49, N. 477, pp 259-272, Sep 1963.
144. Gill, F., Russell, R.J., Pumpability of Residual Fuel Oils, Ind Eng Chem, V. 46, N. 6, pp 1264-1265, Jun 1954.
145. Wyllie, D., Taylor, W.E.L., The Practical Conditions of the Storage Admiralty Fuel Oils, J Inst Petr, V. 46, N. 437, pp 128-142, May 1960.
146. Davenport, T.C., Russell, R.J., The Full-Scale Pumping of Admiralty Fuel Oil and its Relation to Laboratory Tests, J Inst Petr, V. 46, N. 437, pp 143-160, May 1960.
147. Wyllie, D., James, J.T., The Study of Fuel Oil Pumpability Using a Laboratory Pumping Rig, J Inst Petr, V. 46, N. 437, pp 162-182, May 1960.
148. Ackroid, G.C., Hosking, D.E.M., Lowe, A.G., The Development of a Test to Predict the Pumpability of Admiralty Furnace Fuel Oils, J Inst Petr, V. 46, N. 438, pp 189-199, Jun 1960.
149. Russell, R.J., The Yield Value of Admiralty Fuel Oil, J Inst Petr, V. 46, N. 438, pp 199-208, Jun 1960.
150. _____, Low Temperature Flow Properties of IP Fuel Oil Flow Panel, J Inst Petr, V. 47, N. 446, pp 57-73, Feb 1961.
151. Davenport, T.C., The Control of Pumpability of Industrial Fuel Oils, J Inst Petr, V. 52, N. 507, pp 65-87, Mar 1966.
152. _____, The Development of a Pumpability Test for Fuel Oils. Work of IP Panel ST-B-5 Leading to the Adoption of IP Method 230/69, J Inst Petr, V. 55, N. 541, pp 36-47, Jan 1969.

153. Russell, R.J., Chapman, E.D., The Pumping of 85°F Pour Point Assam (Nahorkatiya) Crude oil at 65°C, J Inst Petr, V. 57, N. 554, pp 118-128, March 1971.
154. Wyllie, D., Viscosities of Light Furnace Fuel Oils in Underground Storage, J Inst Petr, V. 72, N. 562, pp 178-87, Jul 1972.

VI. ALPHABETICAL BIBLIOGRAPHY

(Starred entries are also contained in the Section V, List of References.)

1. Aboul-Ghert, A.K., Abdon, I.K., "Hydrotreating Studies on a Straight-run Gas Oil Fraction", J Inst Petr, V. 58, p. 305, 1972.
- * 2. Ackroid, G.C., Hosking, D.E.M., Lowe, A.G., The Development of a Test to Predict the Pumpability of Admiralty Furnace Fuel Oils, J Inst Petr, V. 46, N. 438, pp 189-199, Jun 1960.
3. Agrawal, K.M., Anand, K.S., Separation of microcrystalline waxes from crude oil tank bottom sediments by solvent precipitation, Indian J Technol, V. 14, N. 10, pp 516-517, 1976.
4. Akchulpanov, A.G., Isupov, Yu G., Sakharov G.V., Determining Optimum Parameters for Injecting and Withdrawing Hydrocarbons from Underground Storage Structures Formed in Rock Salt Deposits, Neft Khoz, N. 7, pp 56-59, Jul 1969 (In Russian).
- * 5. Allbright, C.S., Schwartz, F.G., Ward, C.C., "Diesel Fuel Stability Testing", Project Serial No. SR-001-06-02 (BuShips), Bartlesville Petroleum Res. Center, Bartlesville, OK, Oct 1966.
- * 6. Allbright, C.S., Whisman, M.L., Schwartz, F.G., The Use of Tritium Tracer Techniques in Studies of Gasoline Storage Stability, U.S. Bureau Mines, Rept Invest. N. 6373, 17 p., 1964.
- * 7. Allen, C.F.H., Young, D.M., and Gilbert, M.R., "Indole Formation from Pyrroles", J Org Chem, V. 2, p. 235, 1937.
8. Allison, J.P., Criteria for Quality of Petroleum Products, Applied Science Publishers, Ltd, 1973.
9. Anderson, R.E., "Comparison of Predictive Tests for Diesel Fuel Stability", U.S. Navy Marine Engrg. Lab., AD 448988L, 8 Sep 1964.
- * 10. Andreeva, E.M., Chernikin, V.I., Thermal Interference in a Series of Underground Storage Cavities, IZV Vysshikh Uchebn Zavedenii Neft I Gaz, V. 8, N. 3, pp. 85-89, 1965.
- * 11. Azev, V.S., Kuznetsova, L.N., Stability of the Color of Ethylated Gasolines During Underground Storage, Transp Khranenie Nefti Nefteprod, N. 7, pp 28-29, 1975 (In Russian).
- * 12. Azev, V.S., Kuznetsova, L.N. Malykhin, V.D. Marinchenko, N.I., Results of Tests of Automobile Gasolines by a Complex of Methods of Qualification Evaluation Following Their Long Time Storage in Salt Formations, Transport I Khranenie Nefteproduktov I Uglevodored., N. 2, pp 1-4, 1977 (In Russian).
- * 13. Azev, V.S., Kuznetsova, L.N. Marinchenko, N.I., Effect of Rock Salt and Brines on the Quality of Automotive Gasolines during Underground Storage, Transp Khranenie Nefti Nefteprod, N. 9, pp 20-23, 1974 (In Russian).

- * 14. Azev, V.S., Seregin, E.P., Gladkikh, V.A., Stryuk, N.V., Skurodin, G.B., Kuznetsova, L.N., Long-Term Storage of Jet Fuel T-1 in Underground Reservoirs Formed in Rock Salt Formations, Transp Khranenie Nefti Nefteprod, N. 4, pp. 19-22, 1976 (In Russian).
- 15. Azev, V.S., Stryuk, N.V., Effect of Temperature on the Chemical Stability of Fuels, Khim Tekhnol Topl Masel, N. 11, pp 42-44, 1975 (In Russian).
- * 16. Bachman, W.A., Crude to Flow to U.S. Strategic Storage, U.S. Federal Energy, Oil Gas J, V. 75, N.21, pp 26-27, May 23, 1977, in Chem Week, V. 170, N. 21, p. 17, May 25, 1977.
- * 17. Bagnetto, L., Thermal Stability of Hydrocarbon Fuels, Phillips Petroleum Co., Bartlesville, OK, Research Dev. Rept No. 4559-66R, 2p, Sep 1966, AD-621 531.
- * 18. Bagnetto, L., Thermal Stability of Hydrocarbon Fuels, Phillips Petroleum Co., Bartlesville, OK, 15 Aug 1965, 2p, Contract AF33 657 10639, USGRDR6521.
- * 19. Bagnetto, L., Thermal Stability of Hydrocarbon Fuels, Phillips Petroleum Co., Bartlesville, OK Research Div. Quarterly Progress Rept No. 4236-65R, 72p., 1 Jul-31 Aug 1965.
- * 20. Bagnetto, L., Schirmer, R.M., Thermal Stability of Hydrocarbon Fuels, Phillips Petroleum Co., Bartlesville, OK, Research Div, Rept No. 4390-66R, 90p., Mar 16, 1955.
- * 21. Bartleson, J.D., Shepherd, C.C., How to Select Gasoline Antioxidants, Hydrocarbon Process Petrol Refiner, V. 43, N. 8, p. 153-158, Aug 1964.
- * 22. Bassler, G.D., Smith, J.R., Fundamentals of Fuel Stability, Stanford Research Institute, Final Report for Department of the Army, 1961.
- 23. Becker, H., Review on Corrosion Protection of Fuel Oil Storing Tanks, Chem Tech Ind, V. 65, N. 26, pp 1001-9, 1969 (In German).
- * 24. Bentur, I., Babitz, A., Manor, P., Rocker, K.I., "Storage Stability of Diesel Fuels", Israel Journal of Technology, V. 5, N. 3, 1967.
- * 25. Berezina, R.M., Gureev, A.A., Azev, V.S., Change in Diesel Fuel Quality During Long-Term Storage in Underground Cavities Prepared in Rock Salt Formations, Transp Khranenie Nefti Nefteprod, N. 2, pp 27-29, Chem Abstr, V. 81, 52013, 1974 (In Russian).
- 26. Beriland, H., Claesson, A., Underground Storage of Oil and Gas, Erdoel Kohle-Erdgas-Petrochem, V. 30, N. 8, pp 357-361, Aug 1977 (In German).
- * 27. Bertolette, W., Rogers, J.D., Improving Fuel Oils Through the Use of Additives, Petr Eng, pp. C41-C46, Nov 1956.

- * 28. Bertollette, W.D., Marvel, H.D., Survey of Roadside Diesel Fuel Filterability", ASTM Symposium of Diesel Fuels, Atlantic City, N.J., Jun 1966.
- * 29. Bol Shakov G.F., The Effect of Gum Formed in the Storage of TS-1 Fuel on its Thermal Oxidation Resistance, Khim Tekhnol Topliv Masel, V. 9, N.1, pp 55-58, Jan 1964.
- * 30. Boltd, K.A., Griffith, S.T., Motor Gasolines and Vaporizing Oil, Ch. 5 in Criteria for Quality of Petroleum Products, J.P. Allison, ed., John Wiley & Sons, New York, 1973.
- * 31. Bowden, J.N., Storage Stability of Federal Specification Gasolines, Southwest Research Inst, San Antonio, TX, Army Fuels and Lubricants Res. Lab., Rept. No. AFLRL-34, 20p., Jul 1974.
- * 32. Brandt, H.W., Abandoned Coal Mine Converted into Man-Made Oil Field, Fenix & Scisson International Inc., Oil Gas J, V.70, N.52, pp 76-78, Dec 25, 1972.
- * 33. Brown, D., Building a National Strategic Petroleum Reserve, Environ Data Serv, pp 10-12, Mar 1977.
- * 34. Burns, H.S.M., Underground Storage for Petroleum--A report on the industry's experience with underground storage for petroleum products, Presented by the Committee on Underground Storage for Petroleum to the National Petroleum Council, Mar 7, 1957.
- 35. Calminder, S.A., Oil Storage Underground: Operation Risks and Maintenance, Petrol Rev, V. 24, N. 286, pp 324-326, Oct 1970.
- 36. Cameron, M.D.E., Independent Storage Business Poised for World-Wide Expansion, Pet Times, V. 80, N. 2031, pp 19, 21, 23, 25, July 9, 1976.
- 37. Caspero, N.A., Development of a Hasty Bulk Fuel Storage Reservoir, Army Engr Res & Dev Labs, Ft. Belvoir, VA, Petrol. Equip. Div., Rept No. AERDL-1842, 221 p., Dec 1965.
- * 38. Cherikov, Ya B., Gureev, A.A., Kuzmina, N.A. Kuzneisov, E.G., The Use of Thermal Cracking Kerosine Stabilized by Autoxidation as a Component of Diesel Fuels, Neftepererab I Neftekhim, N.5, pp 4-7, 1969.
- 39. Chiantella, A.J., Johnson, J.E., Filterability of Distillate Fuels. Part 2. Effect of Fuel Viscosity and Related Factors, Naval Research Lab., Washington, D.C., Rept. No. NRL-5971, AD-421 925.
- 40. Christenson, K., Underground Storage System Floats Oil on Water Bed, Pipeline Gas J, V. 197, N. 7, pp 66, 71, 76, Jun 1970.
- * 41. Christenson, K., Nilsson, S.O., Crude and Product Storage in Man-Made Caverns, Pipe Line Ind, V. 41, N. 6, pp 40-43, Dec 1974.

- * 42. Christenson, K.R., Oil Storage Underground: The Principles of Storage, Petrol Rev, V. 24, N. 286, pp 320-322, Oct 1970.
- 43. Christian, J.G., et al., The Glass Effect in Distillate Fuel Stability, ACS Div Petrol Chem Preprints, V. 2, N. 3, Aug 1957.
- 44. Clark, E.L., Means For Determining Fluid Interface in Underground Storage Space, U.S. 3,284,530, C 11/8/55, F 5/7/63, Phillips Petroleum Co.
- * 45. Clinkenbeard, W.L., How Distillate Fuel Stability is Measured and Controlled, ASTM STP No. 244 - Stability of Distillate Fuel Oils, Boston, Mass., Jun 1958.
- 46. Coats, K.H., Katz, D.L., Underground Storage of Fluids, Ulrich's Books, Ann Arbor, Mich, 575 p., 1968.
- * 47. Cole, C.A. and Nixon, A.C., Stability of Jet Fuels in Storage, U.S. Air Force Technical Report No. 6625, Contract A.F. 33(038)-7277, Nov 1951.
- 48. Collings, H.E., Squerciati, E.C., Additives for Liquid Hydrocarbon Fuels, SAE Paper 221 B, Milwaukee, Wis., Sep 1960.
- * 49. Cross, J.S., Emergency Crude Oil Storage is Advocated, American Petroleum Institute, Oil Gas J, V. 73, N. 15, p 32, Apr 14, 1975.
- 50. Daruwalla, M.P., Crude Storage, Tanks or Caverns, Civis Engrg. ASCE, V. 41, N.4, p 38, Apr 1971.
- * 51. Davenport, T.C., The Control of Pumpability of Industrial Fuel Oils, J Inst Petr, V. 52, N. 507, pp 65-87, Mar 1966.
- * 52. Davenport, T.C., Russell, R.J., The Full-Scale Pumping of Admiralty Fuel Oil and its Relation to Laboratory Tests, J Inst Petr, V. 46, N. 437, pp 143-160, May 1960.
- * 53. Davies, R.L., FEA Eyes Potential Oil Storage Sites, Oil Gas J, V. 73, N. 47, pp 22-23, Nov 24, 1975.
- * 54. Davydov, P.I., Bol'shakov, G.F., and Glebovskaya, E.A., A Study of the Effect of Nitrogen Bases on the Stability of Fuels at High Temperatures, Khim Teknol Topliv Masel, V. 7, N. 10, 1962.
- 55. De Gelis, M., Twelve Years of Exploitation of Underground Storage in Southwestern France, 6th Nat Ass FR Tech Petrol Congr, 6/4-7/69 Pap (In French).
- 56. Dibona, C.J., Should Government Own "Reserves", U.S. Federal Energy Adm, Hydrocarbon Process, V. 55, N. 8, p 17, Aug 1976.
- 57. Donat, G., Tellier, C., Determining a Fuel Oil-Brine Interface in the Annular Space of a Well During the Creation of a Cavity of Dissolving Salt, Rev Ist Fr Petrol Ann Combust Liquides, V. 26, N. 12, pp 1203-1211, 1971 (In French).

58. Dreyer, W., Petromechanics Applied to Oil and Gas Storage, Erzmetal, V. 28, N. 6, pp 265-271, Jun 1975.
59. Dreyer, W., Storage of Energy Carriers in Offshore Caverns, Erdoel Kohle-Erdgas-Petrochem, V. 30, N. 5, pp 205-210, May 1977 (In German).
60. Dreyer, W., Rock Mechanics Problems in the Underground Storage of Crude Oil, Erdoel Erdgas Z, V. 88, N. 7, pp 258-267, Jul 1972 (In German).
- * 61. Dreyer, W.E., Results of Recent Studies on the Stability of Crude Oil and Gas Storage in Salt Caverns, Northern Ohio Geol Soc, Proceedings of the 4th Int Salt Symp, V. 2, pp 65-92, 1974.
- * 62. DuBois, D, Maury, V., Underground Storage of Hydrocarbons at Manosque, France, Northern Ohio Geol Soc, Proceedings of the 4th Int Salt Symp, V. 2, pp 313-321, 1974.
63. Dudka, G.V., Zorina, A.S., Stryuk, N.V., Storage of T-1 Fuel in Subterranean Area Built in Salt Domes, Transp Khranenie Nefti Nefteprod, N. 6, p. 21, Chem Abstr, V. 81-108249, 1971 (In Russian).
- * 64. Elmquist, E.A., A Review of the Distillate Fuel Stability Program, ASTM STP No. 244 - Stability of Distillate Fuel Oils, Boston, Mass., Jun 1958.
- * 65. Englin, B.A., et al., Effect of Nitrogenous Bases on the Thermal Stability of Jet Fuels, Nefteperal Neftekhim, N. 3, pp. 9-11, Chem Abstr, V. 79, 44129j, 1973.
66. Finefrock, V.H., London, S.A., Microbial Contamination of USAF JP-4 Fuels, Dayton Univ Ohio Res Inst, 175p, Contract AF 33(615)-2692, Aug 1966.
67. Fink, R.J., Bancroft, B.A., Palmieri, T.M., The Strategic Petroleum Reserve and Liquefied Natural Gas Supplies, Final Rept, 15 Feb 77, 83p, Contract FEACR04-60918-00.
- * 68. Footner, H.B., Roberts, G.A.H., Microbiological Corrosion of Tanks in Longterm Storage of Gas Oil, Brit Corros J, V. 5, N. 2, p 64, Mar 1970.
- * 69. Garner, M.Q., White, E.W., The Storage Stability of Navy Distillate Fuel For Ships, Naval Ship R&D Ctr, Report 4198, Apr 1974.
- * 70. Gill, F., Russell, R.J., Pumpability of Residual Fuel Oils, Ind Eng Chem, V. 46, N. 6, pp 1264-1265, Jun 1954.
- * 71. Gomm, H., Hieblinger, J., Kuehn, G., German Caverns Store 60-Million-bbl Oil Reserve, Oil Gas J, V. 76, N. 27, pp 60-64, Jul 3, 1978, and V. 76, N. 28, pp 153-158, Jul 10, 1978.

72. Gomm, H, Hieblinger, J., Kuehn, G., New Solution Mining and its Application in The (B.R.D.) Cavern Project at Etzel, Kavernen Bau-Betriebs G.M.B.H., 4th Oesterr, Ges. Erdoelwiss. DGMK JT Meet, (Salzburg 10/4-6/76), D Ges Mineraloelwiss Konlechem, E.V. Compound N., Part 2, pp 683-704, 1976-1977 (In German).
- * 73. Greatorex, R., Thermal Treatment of Light Residual Fuels to Minimize Wax Separation Problems, J Inst Petr, V. 49, N. 477, pp 259-272, Sep 1963.
- * 74. Greatorex, R., Lodwick, J.R., Some Aspects of the Filter-Clogging Properties of Middle Distillates, API Proceedings Div Refining, V. 43, 1963.
- * 75. Grodde, K.H., Process for Detecting an Interface Between Two Media, Especially Between Oil and Brine in the Construction and Operation of Storage Caverns, Ger 2,363,783, C 2/13/75, F 12/21/73.
76. Grow, G.C., Jr., Analysis of Underground Storage, Pipe Line Ind, V. 23, N. 4, pp 31-32, Oct 1965.
77. Grow, G.C., Jr., Underground Storage Continues to Grow, Gas, V. 47, N. 6, pp 31-32, Jun 1971.
- * 78. Grupe, K.H., Malinka, H., Hentschel, G., Determining Motor Fuel Storability, Ger. (East), Patent 93972, Applic No. 150 761, Oct 20, 1970.
- * 79. Gupta, S.D., Iyer, N.V., Pundir, B.P., Antioxidants for Fuels, Chem Age India, V. 22, N. 8, pp 524-527, 1971, Chem Abstr, V. 75-131288.
- * 80. Gyrath, F.W., Dunn, F.R., Smith, A.C., One-Day Stability Tests for Distillate Fuel Oils, ACS Division of Petroleum Chemistry, Chicago Meeting, Sep 1958.
- * 81. Hagemann, E., Germans Look to Salt Domes to Ease Oil Storage Problems, World Petrol, V. 40, N. 6, pp 26-27, Jun 1969.
82. Hague, R.S., Oil Storage Method, Atomic Energy Commission, Washington, D.C., Rept No. PAT-APPL-34 759, Patent 3 643 441, Feb 22, 1972.
- * 83. Halliwell, H., Engine Test of Barge-Stored Diesel Fuels, U.S. Naval Engineering Experiment Station Report No. 620129A, Apr 1959.
- * 84. Haudan, B.O., Worldwide Underground Storage, Oil Gas Europe Mag, V. 3, N. 1, pp 36-38, 41-47, Apr 1977.
85. Hawkins, M.E., Jirik, C.J., Salt Domes in Texas, Louisiana, Mississippi, Alabama, and Offshore Tidelands A Survey, U.S. Bureau of Mines Inform Circ, No. 8313, 80pp, 1966.

- * 86. Hazzard, G.F., The Detection of Micro-Organisms in Petroleum Products, J Inst Petr, V. 53, N. 524, pp 267-74, Aug 1967.
- 87. Heckard, J.M., Langill, R.F., Potential Underground Storage of Hydrocarbons Along the Eastern Seaboard, SPE of Aime Eastern Reg Mtg Preprint No. SPE-4159, 12 pp, 1972.
- * 88. Hendey, N.I., Some Observations on Cladosporium Resinae as Fuel Contaminant and Possible Role in Corrosion of Aluminum-Alloy Fuel Tanks, Trans Brit Mycological Soc, V. 47, N. 4, pp 467-75, 1964, (Abstr) Corrosion Abstr, V. 4, N. 5, p 345, Sep 1965.
- * 89. Hill, E.C., Biological Problems of Fuel Storage, Chem Brit, V. 1, N. 5, p 190, May 1965.
- * 90. Hill, J., FEA (U.S. Federal Energy Adm) Unveils Early Storage Plant, Oil Gas J, V. 74, N. 17, p 78, Apr 25, 1976.
- 91. Hilts, F.H., Purification of Fuel Oils by Centrifugal Force, Amer Soc Test Mater, Spec Tech, Publ, STP 531, pp 121-132, 1973.
- * 92. Hitzman, D.O., Linnard, R.E., Control of Microbial Growths in the Storage of Petroleum Fuels, Phillips Petroleum Co., 7th World Petrol. Cong. (Mexico City 4/2-8/67), Paper N. PD-36(2).
- * 93. Hofrichter, E., Storage of Energy Fuels in Salt Caverns. Geological and Mineralogical Problems, Erdoel Ergas Z, V. 88, N. 8, pp 284-94, Aug 1972, Pet Abstr, V. 12, N. 52, ABSTR No. 168 136, Dec 23, 1972.
- 94. Holloway, H.H., Salt Dome Storage Caverns Feature High Deliverability, Pipeline Gas J, V. 198, N. 14, pp 28, 32, 36, 41, 44, 46, Dec 1971.
- * 95. Houlihan, W.J., Indoles, V. 25, Part I of Heterocyclic Compounds, Remers, W.A. and Brown R.K., eds., Wiley and Sons, N.Y., 1972.
- * 96. Isupov, Yu, G., Khaziev, N.N., Abakumov, V.A., Exploitation of an Underground Storage Reservoir for Oil Products, Formed in Salt Formations, Neft Khoz, V. 44, N. 10, pp 61-64, Oct 1966 (In Russian).
- * 97. Ivanov, A.L., Romanov, A.N., Gladkikh, V.A., Kachurina, G.V., Alekseeva, M.P., Englin, B.A., Change in the Properties of Hydrogenated Fuels During Long-Term Storage, Khim Tekhnol Topl Masel, N. 5, pp 27-30, Chem Abstr V. 83-149986, 1975 (In Russian).
- * 98. Jackson, H.M., Morton, R.C.B., Ford Mulls Strategic-Storage System, Oil Gas J, V. 72, N. 48, pp. 34, Dec 2, 1974.
- 99. Jacoby, C.H., Solution Mining of Salt and Storage of Industrial Fluids, U.S. 3,724,898, C 4/3/73, F 3/29/71.

- *100. Jansson, G., Rock-Cavern-Type Storage Can Be Cheaper Option, Oil Gas J., V. 72, N. 43, pp 74-76, 79-82, Oct 28, 1974.
- *101. Jirik, C.J., Weaver, L.K., A Survey of Salt Deposits and Salt Caverns--Their Relevance to the Strategic Petroleum Reserve, US Federal Energy Adm. Rep. No. FEA/S-76/310, 72p, July 1975; PB-255,948/2GA (AO).
- 102. John, E., Apparatus for Testing Underground Oil Storage Reservoirs for Leaks, Tech Uberwachung, V. 10, N. 3, pp 77-80, 1969 (In German).
- *103. Johnson, C.R., Fink, D.E., Nixon, A.C., Stability of Aircraft Turbine Fuels, Ind. Eng. Chem., V. 46, 2166, 1954.
- *104. Johnston, R.K., Improving the Storage Stability of Jet Fuels by the Use of Additives, Soc Automotive Engrs Mtg Paper N. S393, (ABSTR) SAE Journal, V. 72, N. 9, p 189, Sep 1964.
- *105. Johnston, R.K., Anderson, E.L., A Review of Literature on Storage and Thermal Stability of Jet Fuels, U.S. Dept Com Office Tech. Serv. Publ., 30p., Jan 1964, (ABSTR) Mater Res Std, V. 4, N. 9, p 520, Sep 1964.
- *106. Johnston, R.K., Monita, C.M., Jet Fuel Stability and Effect of Fuel-System Materials, SwRI-RS-515, 47p, Contract: AF-33(625)-2327, Feb 1968, AD-828 472/9ST.
- *107. Kanesaki, K., Takenouchi, Y., Gum Formation in Catalytically Cracked Gasoline on Storage, Sekiyu Gakkai Shi, N. 4, pp 238-242, 1962 (English Transl) Inter Chem Eng, V. 4, N. 1, p 158-164, Jan 1964.
- 108. Katz, D.L., Outlook for Underground Storage, Northern Ohio Geol Soc, Proceedings of the 4th Int Salt Symp, V. 2, pp 253-258, 1974.
- 109. Kaudinya, H., Lorenze, H., Relotius, P.C., Offshore Terminal with Underground Storage, Erdoel Erdgas Z, V. 93, N. 7, pp 242-245, Jul 1977 (In German).
- 110. Kaufmann, A., Oil and Gas Storage in Subsurface Formations, Erdoel Erdgas Z, V. 92, N. 9, pp 296-300, Sep 1976 (In German).
- 111. Kaundinya, H., Lorenzen, H., Relotius, P.C., Offshore-Terminal with Underground Storage at Sea, Oil Gas Europe Mag, V. 3, N. 2, pp 39-40, 45, 1977.
- *112. Kirchner, J.P., Osterhout, D.P., Schwinderman, W.R., Improvement of Distillate Fuels by Additive and Refining Techniques, ASME Paper No. 55-A-213, Annual Meeting Chicago, Nov 1955.
- *113. Kitchen, G.H., Fuel Storage Life, NPRA Technical Paper 66-14, San Antonio, Texas, Mar 1966.

- *114. Kite, W.H., Jr., Stephens, G.G., Fuel Oils, Including Domestic Heating Oils, Ch. 9 in Criteria for Quality of Petroleum Products, J.P. Allison, ed., John Wiley & Sons, New York, 1973.
- *115. Kittredge, G.D., Thermal Stability of Hydrocarbon Fuels, Phillips Petrol. Co, Bartlesville, OK, 159p, Contract AF33 616 7241, Jul 1963, PB-166 959.
- *116. Kittredge, G.D., Thermal Stability of Hydrocarbon Fuels, AF33(616) 7241, AD-285 636.
- *117. Kittredge, G.D., Streets, W.L., Ratchford, R., Thermal Stability of Hydrocarbon Fuels, U.S. Dept of Com. Office Tech. Serv., 1961, AD262 338.
- 118. Kleiger, L.J., The Effect of Petroleum Fuel Storage Stability on Prepositioning Costs, 44p, Contract: F44620-67-C-0045, AD-702 430, Jan 1970.
- *119. Klemme, D.E., Leonard, J.M., Inhibitors for Marine Sulfate-Reducing Bacteria in Shipboard Fuel Storage Tanks, Nav. Res. Lab., Washington, D.C., U.S. Nat. Tech. Inform Ser., 22pp, 1971, AD 730024.
- 120. Klyukvin, I.N., Kolosov, A.V., Modeling the Process of Leaching Out a Chamber for Gas-Oil Storage in Salt Layers of Complex Structure, Gazovoe Delo, N. 7, pp 20-23, 1972, (ABSTR) Pet Abstr, V. 13, N. 18, Abstr No. 173 785, May 5, 1973.
- 121. Knecht, A.T. Jr., Kools, J.W., Muhibaier, D.J., Rizzuto, A.R., Microbial Utilization of Hydrocarbon Fuel Formulations with the Production of Gums, Slimes, Sludge and Surface Active Compounds, Contract DA-19-129-AMC-88(N), Oct 1965.
- 122. Kohsling, J., Piekarz, J., Development of the Methods of Underground Gas and Petroleum Products Storage, Nafta (Pol), V. 31, N. 1, pp 18-23, Jan 1975 (In Polish).
- *123. Kolobielski, M., Estimation of Dipole Moment of Oxidized Gasolines: A Potential Method for Evaluating Effectiveness of Additives, ACS Div Petrol Chem Preprints, V. 21, N. 4, Aug 1976.
- 124. Kuehne, G., The Storage of Gases and Liquids in Subterranean Cavities, Chem Ing Tech, V. 39, N. 17, pp 1036-1040, Sep 11, 1967 (In German).
- 125. Kuehne, G., Keutsche Erdoel, A.G.; German Refinery Develops Successful Underground Butane Storage Facility, World Petrol, V. 36, N. 1, pp 42-43, 47, Jan 1965.
- 126. Kuenner, R.E., Blankenship, J., McCoy, P.F., Optimal Drawdown Strategy for Strategic Petroleum Reserves, Rept No. IDA-P-1252, Contract: FEA-CR-02-60857-00, PB-265 838/3ST.

127. Kukin, I., Additives for Refinery Use in Manufacturing, Processing, and Marketing, NPRA Paper 66-63, Wichita, Kansas, Jun 1966.
128. Kunze, P., Wichlacz, H., Suske, S., Underground Storage of Liquid and Gaseous Products, Chem Tech, V. 27, N.3, pp 148-153, Mar 1975 (In German).
129. Kuznetsove, L.N., Skvorodin, G.B., Seregin, E.P., Gladkikh, V.A., Stryuk, N.V., Azev, V.S., Long-Term Storage of Jet Fuel T-1 in Underground Reservoirs Formed in Rock Salt Formations, Transp Khranenie Nefti Nefteprod, 1976, N. 4, pp 19-22 (In Russian), Chem Abstr, V. 85-195048.
- *130. Lambrich, K.H., Kuehns, G., Experiences Gained in Creation and Operation of Caverns in Salt Domes with a Large Content of Impurities, Proceedings of the Ninth World Petroleum Congress, V.5, pp 81-88, 1975.
- *131. Lander, H.R., Jr, Stability of High-Temperature, Hydrocarbon Jet Fuels During Storage, Air Force Aero Propulsion Lab, Wright Patterson AFB, Rept No. APL-TDR-64-107, 2p, Nov 1964, AD-610 591.
- *132. Lander, H.R., Jr., Storage Behavior of High-Temperature Jet Fuels, Soc of Automotive Engrs Mtg Paper, N. 5391, SAE Journal, V. 72 N. 9., p189, Sep 1964.
133. Landgraf, H., Corrosion Inhibitor for Fuel Oil Storage Tanks, Ger Offen, V. 700827, 11p, Patent No. 1908764.
134. Langer, M., Engineering-Geological Problems of Underground Storage of Oil and Gas, Geol Jahrbuch, V. 90, pp 315-57, Feb 1972, Pet Abstr, V. 13, N.9, ABSTR No. 170 927, Mar 3, 1973.
- *135. Leas, A.M., Reclamation of JP-6 Type Jet Fuels Which Became Thermally Unstable During Storage, 2p, Contract: AF33 657 11097, AD-601 984, Jun 1964.
- *136. Lechler, S., Experience Gained in the Construction and Operation of Lesum Cavern Storage, Erdoel Erdgas Z, V. 90, N. 3, pp 80-87, Mar 1974 (In German).
137. Lechler, S., Lesum Cavern Storage. Construction and Operation, Erdoel Erdgas Z, V. 90, N. 3, pp 80-7, 1974, (In German).
- *138. Lechler, S., Here's How Mobil Prepares Storage Caverns in German Salt-Domes, Petrol Petrochem Int., V. 11, N. 12, pp 64-68, 73, 80C, Dec 1971.
- *139. LePera, M.E., Investigation of the Autoxidation of Petroleum Fuels, U.S. Army Coating and Chemical Lab, Aberdeen Proving Ground, Rept No. CCL-204, 2p, Jun 1966, AD-641 270.

- *140. LePera, M.E., Investigating the Elastomer Environmental Effects on the Storage Stability of Military Fuels, U.S. Army Coating and Chemical Lab., Aberdeen Proving Grounds, Rept No. CCL279, 27p, Apr 1970, AD-704 707.
- *141. LePera, M.E., Sonnenburg, J.G., Storage Stability of Automotive Diesel Fuels, U.S. Army Coating and Chemical Lab, Aberdeen Proving Ground, Rept No. CCL-315, 27p, Oct 1972, AD-752 906.
- *142. LePera, M.E., Sonnenburg, J.G., How Stable Is Diesel in Storage, Hydrocarbon Process, V. 52, N. 9, pp 111-115, Sep 1973.
- 143. Lichtblau, J.H., Urges U.S. Strategic Oil Storage, Petroleum Industry Research Foundation, Oil Gas J, V. 71, N. 23, pp 28, Jun 4, 1973.
- 144. Lindeman, R.P., Lawrence, D.K., Wagner, T.O., Classification of Diesel Fuels, SAE Paper 680467, Detroit, Michigan, May 1968.
- 145. Lodwick, J.R., Chemical Additives in Petroleum Fuels: Some Uses and Action Mechanisms, Journ Inst Petrol, V. 50, Nov 1964.
- 146. Losikov, B.V., Petroleum Products, Properties, Quality, Application, Edited Trans. of Mono., part 1, Nefteprodukty, Svoistva, Kachestvo, Primeneniya, Moscow, 236p, Rept No. FTD HT 23-347-68-Pt-1, AD-698 546, Aug 22, 1969.
- 147. Losikov, B.V., Petroleum Products, Properties, Quality, Application, Part 2, Nefte produkty, Svoistur, Kachestve, Primemeniya, Moscow 1966, 238p, Rept No. FTD-HT-23-347-68-Pt-2, Aug 22, 1969, AD 698 546.
- 148. Luebben, H., Gralla, J., Synopses/Criteria for Storing Gas in German Petroleum and Natural Gas Reservoirs, Erdoel Kohle Erdgas Petrochem Brennst-Chem, V. 29, N. 3, pp 124, Mar 1976.
- 149. Lumsden, A., Strategic Oil Stocks Going Up, Petroleum Economist, V. 44, N. 6, p 223 (2), Jun 1977.
- 150. Lux, K.H., Rokahr, R.B., Lorenzen, H., Requirements for Salt Cavity Stability Analysis, Erdoel Erdgas Z, V. 93, N. 2, pp 67-72, 1977 (In German).
- *151. Luxo, A., Roux, C.B., Schlumberger, E., Souquet, G., Underground Storage of Energy--Safeguarding of the Environment, 9th World Energy Conf Trans, V. 7, pp 191-210, 1975 (In French).
- *152. MacDonald, J.W., Jones, R.T., Predictive Type Tests for Storage Stability and Compatibility of Diesel Fuels, ASTM STP No. 244: Stability of Distillate Fuel Oils, Boston, Mass., Jun 1958.
- 153. Malito, E.A., The Ace in the Hole--Underground Storage, Pipe Line Ind, V. 25, N. 6, pp 42-44, Dec 1966.

- *154. Malysheva, I.V., Melenteva, N.I., Study of the Thermal Stability of Jet Fuels Freshly Prepared and After Protracted Storage, Khim, I Tekhnol Topl I Masel, V. 13, N. 7, pp 46-47, 1968.
- 155. Mayo, F.R., et al., The Chemistry of Jet Turbine Fuel Deposits and Their Precursors, ACS Div of Pet Chem, Preprints V. 20, N. 1, 1965.
- 156. McBrien, R., The Use of Economy Fuels on Diesel Locomotives, ASME Paper 57-RR-6, Chicago, IL, Apr 1957.
- 157. McCarthy, D.F., Underground Storage Facilities for Gaseous and Liquid Hydrocarbons, Pipeline Gas J, V. 199, N. 3, pp 52-56, 58, Mar 1972.
- 158. McGuire, T.W., Letters (To the Editor)/Storing Oil in Depleted Fields, Oil Gas J, V. 74, N. 32, pp 17, 19, Aug 9, 1976.
- *159. Miller, C.O., Arnold, A.P., Resume of Additives for Diesel Fuels and Their Function, SAE Mid-Year Meeting, Detroit, MI, 1970.
- 160. Millet, J.L., Underground Storage in France, Gaz Aujourd'Hui, V. 96, N. 2, pp 55-63, Feb 1972 (In French).
- *161. Minor, H.B., Nixon, A.C., and Thorpe, R.E., Stability of Jet Turbine Fuels, U.S.A.F. WADC TR 53-63 (AD 118084), Feb 1957. Part IV, USAF WADC TR 53-63 (AD 118085) Feb 1957.
- 162. Moore, C.C., Lakin, W.P., Distribution and Storage Problems with Diesel Fuels, Philadelphia, PA, February 1977.
- 163. Morfeldt, C.O., Storage of Oil in Unlined Caverns in Different Types of Rock, 14th U.S. Nat Comm Rock Mech New Horizons in Rock Mech Symp Proc, pp 409-420, 1973.
- 164. Mullagalyamov, T.S., Gareev, F.G., Khafizova, L.M., Suleimanova, E.G., On the Method of Determining Actual Losses of Petroleum During Its Collection, Treatment, and Storage, Bashk Nauchno Issled Inst Pererab Nefti USSR Neft Khoz, N. 12, pp 46-8, 1975, Chem Abstr, V. 84-166999 (In Russian).
- 165. Munger, G.C., (A Discussion of) Sulfides...Their Effect on Coatings and Substrates, Natl. Assoc. Corrs. Eng. Corros./77' Meet. (San Fran. Mar 1977) Mater Performance V. 17, N. 1 pp 20-23, Jan 1978.
- *166. Nagy, K.V., Pokoj, D.E., Navy Fuel Interactions with Additives. Phase I. An Investigation of Side Effects from a Commercial Biocide, U.S. Nat. Tech. Inform. Serv., 25, 1975, AD-A018966.
- *167. Nixon, A.C., Autoxidation and Antioxidants of Petroleum, Ch. 17 in Autoxidation and Antioxidants, W.O. Lundberg, ed., V. II, Interscience, New York, 1962.

- *168. Nixon, A.C., Cole, C.A., Minor, H.B., The Effects of Composition and Storage on Laboratory Properties of Jet Fuels, SAE Paper 524, Jun 1955.
- 169. Nixon, A.C., Thorpe, R.E., The Effect of Composition on the Stability and Inhibitor Response of Jet Fuels, ACS Div. Petrol. Chem. Preprints, V. 1, N. 3, Aug 1956.
- *170. Noel, T., Hill, J., Field Work (IS) Near for U.S. Strategic-Storage Plan, U.S. Federal Energy Adm, Oil Gas J, V. 74, N. 41, pp 80, Oct 11, 1976.
- *171. Noel, T.E., Strategic Petroleum Reserve Program Will Require New Lines, Pipe Line Ind, V. 46, No. 5, pp 35-38, May 1977.
- 172. Nowack, C.J., Analysis and Testing of JP-5 Fuel Derived from Coal, 57p, Rept No. NAPTC-PE-99, AD-A036 073/5ST, Jan 1977.
- *173. O'Donnell, J.P., Nine Brine Pits to Serve Underground Storage, Oil Gas J, V. 70, No. 38, pp 100101, Sept 18, 1972.
- *174. Offenhauer, R.D., Brennan, J.A., and Miller, R.C., Sediment Formation in Catalytically Cracked Distillate Fuel Oils, Ind Eng Chem, V. 49, 1265, 1957.
- 175. Offenhauser, R.D., et al., Sediment Formation in Catalytically Cracked Distillate Fuel Oils, ACS Div Petrol Chem Preprints, Vol. 1, No. 3, August 1956.
- *176. Orvell, G., Drilling Caverns for Underground Storage, Petroleum Engineer, V. 49, N. 6, p 70 (3), June 1977.
- *177. Oswald, A.A., Noel, R., Role in Pyrroles in Fuel Instability, J Chem Eng Data, V. 6 (2), p. 294, 1961.
- 178. Oude-Alink, B.A, Hutton, R.P., Hexahydropyrimidines as Fuel Additives, Petrolite Corp, Patent 3936279, Nov. 2, 1973.
- 179. Pachet, M., Trotter, J.G., Underground Storage, Petrol Rev, V. 28, N. 335, pp 727-732, Nov 1974.
- 180. Paktank Storage Co., Petroleum and Storage, Petroleum (London), V. 27, N. 4, pp 172-79, Apr 1964.
- 181. Palmeiri, T.M., Strategic Storage, Superports and Salt Domes: A Synthesis, 26p. Contract: W-7405-eng-48, UCID-16455, Feb 22, 1974.
- 182. Pelissier, Y., Storage of Oil at Sea...Underwater Tanks, Publ Inst Fr Pet Collect Colloq Semin, N. 23, pp 159-85, 1972, Pet Abstr, V. 12, N. 35, ABSTR No. 163 885, Aug 26, 1972.
- 183. Persson, S.A.G., Oil Storage Underground: Mechanical Equipment and Controls, Petrol Rev, V. 24, N. 286, pp 323-324, Oct 1970.

- *184. Polss, P., What Additives do for Gasoline, Hydrocarbon Processing, V. 52, N. 2, pp 61-68, Feb 1973.
- 185. Premo, J.G., Treating Water Contained in Gasoline Storage Tanks, Nalco Chemical Co, Patent No. 3880752, Mar 3, 1974.
- *186. Read, W., LOOP Plans Salt-Dome Crude Storage, Oil Gas J, V. 73, N. 30, pp 44-45, Jul 28, 1975.
- *187. Rischmuller, H., Salt Caverns for the Storage of Crude Oil and Natural Gas in West Germany. A General Discussion of the Technical and Economic Aspects, Erdoel Erdgas Z, V. 88, N. 7, pp 240-248, Jul 1972 (In German).
- *188. Ritchie, J., A Study of the Stability of Some Distillate Diesel Fuels, J Inst Petr, V. 51, N. 501, Sep 1965.
- *189. Roberts, G.A.H., Microbiological Corrosion of Tanks in Long-Term Storage of Gas Oil--2. Further Bacterial Studies and Use of Borax as a Biocide, Brit Corros J, V. 8, N. 2, pp 86-88, Mar 1973.
- *190. Roberts, G.A.H., Microbiological Corrosion of Tanks in Long-Term Storage of Gas Oil, Brit Corros J, V. 4, N. 6, pp 318-321, Nov 1969.
- *191. Roehr, H.U., Factors Influencing the Leaching of an Underground Storage Reservoir in a Salt Dome in View of Obtaining Information for Planning and Control Operations, Erdoel Kohle, Erdgas, Petrochem, V. 22, N. 11, pp 670-679, 1969 (In German).
- *192. Roels, R., Testing the Oxidation of Motor Fuel in the Presence of Copper, J Inst Petr, V. 50, N. 481, pp 22-26, Jan 1964.
- 193. Rohl, G.E., Organic Linings for Concrete Storage Tanks for Petroleum Fuels, Naval Research Lab, May 75, Rept No. NRL-MR-3039, AD-A010 514/8ST.
- 194. Ruf, H., Methods of Estimation of Storage Stability of Motor Fuels in Laboratory And Behavior in Bulk Storage in Practice, Schweiz Arch Angew Wiss Tech, V. 29, pp 428-444, 1963, J Inst Petr, V. 50, No. 487, pp 136A, Jul 1964.
- *195. Ruhl, W., Large Scale Underground Storage of Gaseous and Liquid Hydrocarbons, Erdoel Kohle, Erdgas Petrochem, V. 24, N. 5, pp 299-309, May 1971 (In German).
- *196. Russell, R.J., The Yield Value of Admiralty Fuel Oil, J Inst Petr, V. 46, N. 438, pp 199-208, Jun 1960.
- 197. Russell, R.J., Chapman, E.D., The Pumping of 85°F Pour Point Assam (Nahorkatiya) Crude Oil at 65°C, J Inst Petr, V. 57, N. 554, pp. 118-128, Mar 1971.

- *198. Sablina, Z.A., Gureev, A.A., Kukushkin, A.A., Melent'eva, N.I., Englin, B.A., Fomina, A.M., Changes in the High-Temperature Properties of Jet Fuels During Prolonged Storage, Khim Tekhnol Topl Masel, V. 15, N. 12, p 39-42, 1970 (In Russian).
199. Saver, R.W., A Mechanism for Organic Sediment Formation in Heating Oils, ACS Div Petr Chem Preprints, V. 3, N. 3, Aug 1958.
- *200. Schmidt, K., Technical and Economical Aspects of Leaching of Oil and Gas Storage Caverns at the EPE Salt Mines, Haus Tech Meet (Essen 6/3-4/75) Tech Mitt, V. 68, N. 9-10, pp 363-68, Sep-Oct 1975 (In German).
201. Schou, L., Atterby, P., Microbial Corrosion Hazard in Fuel Storage Tanks in the Presence of Corrosion Inhibitors, Brit Corros J, V. 8, N. 1, pp 38-40, 1973.
- *202. Schwartz, F.G., Allbright, C.S., Ward, C.C., Storage Stability of Gasoline: Oven Test for Prediction of Gasoline Storage Stability, Bureau of Mines, Rept No. RI-7197, 32p, Dec 1968, AD 683 748.
- *203. Schwartz, F.G., Whisman, M.L., Allbright, C.S., Ward, C.C., Storage Stability of Gasoline. Development of a Stability Prediction Method and Studies of Gasoline Composition and Component Reactivity, U.S. Bureau of Mines., Bull. N. 660, 64p, PB-212 555, Sep 1972.
- *204. Schwartz, F.G., Whisman, M.L., Allbright, C.S., Ward, C.C., Storage Stability of Gasoline. Fundamentals of Gum Formation, Including a Discussion of Radiotracer Techniques, US Bureau of Mines Bull N. 626, 44p, 1964.
205. Semenov, V.I., Method for Dissolving Salt Deposits for Underground Gas and Oil Storage, USSR 168,622, F 5/26/62.
- *206. Serata, S., Use of Salt Cavities for Storage of Gas and Fluid Fuels in the Energy Crisis, Aime Soc Min Eng Annu Meet (Dallas Feb 23-28, 1974) Prepr No. 74-H-64, 14p, Pet Abstr, V. 15, N. 15, Abstr No. 203 465, Apr 12, 1975.
207. Shagin, V.M., Merzlova, T.S., Avdeev, N.V., Afanaseva, N.A., Zrelov, V.N., Bulavin, V., Effect of Carbon Dioxide on the Storage Stability of Fuel, Khim Tekhnol Topl Masel, V. 18, N. 8, pp 45-48, 1973 (In Russian).
208. Shook, A.M., Underground Cavern for Storage of Hydrocarbons, U.S. 3,552, 128, C 1/5/71, F 6/2/69; Texaco Inc, 1971.
- *209. Silla, H., Switching Fuel Oils During a National Emergency, Report prepared for the Stratetic Petroleum Reserve Office, DOE, Stevens Institute of Technology, Dec 1977.
- *210. Sirola, J., Utilization of Catalytically Cracked Distillates in the Production of Diesel Fuel, Nafta (Zagreb), V. 13, pp 398-404, 1962, Abstr, J Inst Petrol, V. 49, N. 479, p 231A, Nov 1963.

211. Smith, R., Weeks, J.P., Underground Fuel Storage, Petrol Rev, V. 29, N. 347, pp 767-773, Nov 1975.
212. Sneden, J.A., British-Swedish Underground Oil Storage Venture, Petrol Times, V. 79, N. 2003, pp 25, 31, Mar 7, 1975.
- *213. Solovjev, A.N., Filinov, M.V., Kiselev, A.I., Theoretical Fundamentals of Calculations and Results of Operation of the Semi-Commercial Gatchiuskaja Underground Gas Storage, Ninth World Petroleum Congress Proceedings, V. 5, pp 109-114, 1975.
214. Sparenberg, H., Storage of Liquid Petroleum Products, Oil & Gas, V. 10, N. 12, p 34, 1965, Abstr, Riv Combust, V. 20, N. 9, p 108S, Sep 1966.
- *215. Stavinocha, L.L., LePera, M.E., A Review of Diesel Fuel Deterioration and Related Problems, Southwest Research Inst., San Antonio, TX, Army Fuels & Lubricant Res. Lab, Rep. No. AFLRL-88, 28p, May 1977, AD-A043566/9ST.
- *216. Strigner, P.L., Long Term Storage of Hydrocarbon Fuels in Coated Drums. Part III. Examination of Fuels After Five Years of Storage, National Research Council of Canada, Rept No. DME-MP-30, 26p, May 13, 1964, AD-678478.
217. Stryuk, N. Azev, V.S., Raitses, F.M., Prokhorova, S.D., Storage of Ethylated Gasolines in Subterranean Vessels, Transp Khranenie Nefti Nefteprod, N. 12, pp 17-19, 1973 (In Russian).
218. Stryuk, N.V., Gorobtsova, E.P., Raitses, F.M., Diesel Fuel Storage in Subterranean Areas Built in Salt Beds, USSR, Transp Khranenie Nefti Nefteprod, N. 1, pp 23-5, 1971 (In Russian).
219. Stryuk, N.V., Gureev, A.A., Azev, V.S., Gerasimova, G.N., Sampling of Petroleum Products from an Underground Reservoir Installed in a Geological Formation Containing Rock Salt, Transp Khranenie Nefti Nefteprod, N. 1, pp 20-2, Chem Abstr, V. 81, 52012, 1974 (In Russian).
220. Stryuk, N.V., Gureev, A.A., Azev, V.S., Gerasimova, G.N., Sampling of Petroleum Products From an Underground Reservoir Installed in a Geological Formation Containing Rock Salt, Transp Khranenie Nefti Nefteprod, N. 1, 20-22, Chem Abstr, V. 81, 52012, 1974 (In Russian).
- *221. Stryuk, N.V., Usacheva, E.V., Effect of Aqueous Media on the Chemical Stability of Fuels, Transp Khranenie Nefti Nefteprod, N. 5, pp 39-40, 1976 (In Russian).
222. Tabary, J., Underground Storage of Petroleum Products, Petrol Rev, V. 27, N. 318, pp 213-217, Jun 1973.
223. Tabary, M., Underground Storage with Artificial Sealing, Rev Assn Franc Tech Petrol, N. 212, pp 61-65, Mar-Apr 1972 (In French).

- *224. Taylor, W.F., Frankenfeld, J.W., Development of High Stability Fuel, Final Report for Phase 1, Naval Air Propulsion Test Center, Contract N00140-72-C-6892, Jan 1975.
- *225. Taylor, W.F., Frankenfeld, J.W., Development of High Stability Fuel, Rept No. EXXON/GRU.17.GAHF.76, 88p, Contract: N00140-74-C-0618, Dec 1976, AD-A038 977/5ST.
- *226. Taylor, W.F., Frankenfeld, J.W., Development of High Stability Fuel, Exxon Research and Engineering Co, Final Rept for Phase 2, Rept: EXXON/GRU.15GAHF.75, Contract:N00140-74-C-0618, 147p, Dec 1975, AD-A020 383/6ST.
- 227. Thompson, R.B., Chenicek, I.A., Druge, L.W., Syman, T., Stability of Fuel Oils in Storage, Ind Eng Chem, V. 43, 935, 1951.
- 228. Trayser, D.A., Heim, G.M., Ellis, W.C., Deterioration of Fuels and Fuel-Using Equipment, Subcontract No. B-70922 (Office of Civil Defense), Battelle Memorial Inst., Columbus, OH, Aug 1967.
- *229. Tumar, N.V., et al., Increasing the Chemical Stability of Jet Fuels with the Use of Antioxidant Additives, Khim Tekhnol Topl Masel, p. 13, Chem Abstr, V. 84, 16705n, 1976.
- *230. Vamos, E., Pataki, E., Storage Stability of Fuel Oils, Energi-agazdalkodas, V. 12, N. 7-8, pp 295-301, 1971 (In Hungarian).
- *231. Von Schonfeldt, H., Corcoran, A.E., Jessen F.W., Feasibility of Storing Large Quantities of Crude Oil in Salt Dome Solution Cavities, North Ohio Geol Soc Proceedings of the 4th Int Salt Symp (Houston 4/8-12/73) V. 2, 277-283, 1974, Pet Abstr, V. 15, N. 12, Abstr No. 202 437, Mar 22, 1975.
- 232. Wachs, A.M., Bentur, S., Kott, Y., Babitz, M., Stern, A.B., Aviation Gasoline Corrosiveness Caused by Sulfate-Reducing Bacteria, Ind Eng Chem Process Design Develop, V. 3, N. 1, pp 65-69, Jan 1964.
- 233. Walters, E.L., Yabroff, D.L., Minor, H.B., Correlation of Predicted and Observed Storage Stability of Cracked Gasoline, Ind Eng Chem, V. 40, p. 423, 1948.
- *234. Ward, C.C., Schwartz, F.G., Review of Some of the Fundamentals of Hydrocarbon Storage Stability, Soc. Auto. Eng. Mtg Paper No. 650936, (1965) SAE Trans, V. 74, Pt. 3, pp. 983-992, 1966.
- *235. Ward, C.C., Whisman, M.L., Goetzinger, J.W., Cotton, F.O., A Radiotracer Study of Turbine Aircraft Fuel Stability, US Bureau of Mines Rep Invest No. 7493, 30p., Mar 1971.
- *236. Weeks, J.P., Smith, R., Underground Fuel Storage, Petroleum Review, pp 767-773, Nov 1975.

- *237. Weismantel, G.E., Underground Storage: Moving Closer to Real Paydirt, Chem Eng, V. 85, N. 2, pp 81-83, Jan 16, 1978.
- 238. Werner, K., Desulfurization and Refining of Gasoline and Jet Fuel by Means of Surface-Active Agents in a Fluidized Bed, Trans of Academia Scientiarum Hungaricae, Acta Chimica, V. 36, N. 1, p 289-298, Rept No. FTD-TT-65-1343.
- 239. Wesselingh, J.A., Mixing of Liquids in Cylindrical Storage Tanks with Side-Entering Propellers, Chem Eng Sci, V. 30, N. 8, pp 973-81, Aug 1975.
- 240. Wettlegren, G., The Importance of Underground Storage to the Offshore Oil Industry, Petrol Times, V. 78, N. 1985, pp 45, 47, 49, May 17, 1974.
- *241. Whisman, M.L., Goetzinger, J.W., Ward, C.C., Storage Stability of Aviation Turbine Fuels: A Radiotracer Technique for Estimating Component Contribution to Thermally Induced Deposits, U.S. Bureau of Mines, Rept No. RI-7325, 28p, Dec 1969, AD-698 742.
- *242. Whisman, M.L., Goetzinger, J.W., Ward, C.C., Storage Stability of High Temperature Fuels. Part III. The Effect of Storage upon Thermally Induced Deposition of Selected Fuel Components and Additives, U.S. Bureau of Mines, Contract: F33615-67-M-5003, 95p, Jun 1970, AD-797 524.
- *243. Whisman, M.L., Ward, C.C., Storage Stability of High Temperature Fuels. Part II. The Effect of Storage Upon Thermally Induced Deposition of Labeled Fuel Components, U.S. Bureau of Mines, Contract: F33615-67-M-5003, 217p, Mar 1969, AD-685 201.
- *244. Whisman, M.L., Ward, C.C., Storage Stability of High Temperature Fuels, U.S. Bureau of Mines, Contract: AF33 615 64 1009, 2p, Feb 1965.
- *245. Whisman, M.L., Ward, C.C., Storage Stability of High Temperature Fuels, U.S. Bureau of Mines, AF-3048, Feb 1967, AD-647 787.
- *246. Whisman, M.L., Ward, C.C., Storage Stability of High Temperature Fuels. Part I. Micro Fuel Coker Tests of Fuel-Radiotracer Blends Before Storage, U.S. Bureau of Mines, Contract: F33615-67-M-5003, 103p, Mar 1968, AD-667 818.
- 247. White, E.W., Storage Stability of Distillate Fuels for Ships, Amer Soc Test Mater Spec Tech Publ, STP. 531, pp 143-66, 1973.
- 248. White, E.W., Nagy, K.V., The Interaction of Distillate Fuels with Inorganic Zinc Coating in Simulated Navy Fuel Tanks, Naval Ship Research & Development Center, Rept No. NSRDC-3928, NSRDC-28-509, 37p, Jul 1973, AD-902 413/2ST.

249. Wiland, S., Use of Mathematical Methods for Investigating the Stability of Residual Fuel, Gospod Paliwami Energ, V. 21, N. 8-9, pp 29-31, 1973 (In Polish).
- *250. Wilke, H., Legal Foundations of Underground Storage, Erdoel Erdgas Z, V. 83, N. 7, pp 246-253, Jul 1967 (In German).
- *251. Windolf, G., Sweden's Underground Millions, Tunnels and Tunnelling, pp 24-26, Sep 1976.
252. Winkler, M.F., Bacher, J.F., Gas Turbine Fuel System Management, SAE Paper 710662, Canada, Aug 1971.
- *253. Wyllie, D., Viscosities of Light Furnace Fuel Oils in Underground Storage, J Inst Petr, V. 58, N. 562, pp 178-87, Jul 1972.
- *254. Wyllie, D., James, J.T., The Study of Fuel Oil Pumpability Using a Laboratory Pumping Rig, J Inst Petr, V. 46, N. 437, pp 162-182, May 1960.
- *255. Wyllie, D., Taylor, W.E.L., The Practical Conditions of the Storage Admiralty Fuel Oils, J Inst Petr, V. 46, N. 437, pp 128-142, May 1960.
- *256. Impurities in Petroleum, Petrolite Corporation Laboratories, Houston, Tx, 1968.
- *257. Strategic Petroleum Reserve Annual Report, February 16, 1978, DOE/RA-0004/1, 1977.
- *258. Strategic Petroleum Reserve Plan, Expansion of the Strategic Petroleum Reserve, Amendment No. 2, Energy Action DOE No. 1, March 1978, DOE/RA-0032/2, UC-13.
- *259. Wintershall A.G.'s Underground Storage Completed, Pet Times, V. 77, N. 1973, p 13, Nov 16, 1973.
- *260. North American Storage Capacity for Light Hydrocarbons, 1977, Gas Processors Association.
- *261. Distillate Fuel Storage Program, Summary Report No. 1, Western Petroleum Refineries Association, Tulsa, OK, 1956.
- *262. Distillate Fuel Storage Program, Summary Report No. 2, Western Petroleum Refineries Association, Tulsa, OK, 1958.
- *263. Navy-CRC Barge Storage Program, Coordinating Research Council (CRC) Report, New York, Jul 1957.
- *264. Low Temperature Flow Properties of IP Fuel Oil Flow Panel, J Inst Petr, V. 47, N. 446, pp 57-73, Feb 1961.
- *265. The Development of a Pumpability Test for Fuel Oils, Work of IP Panel ST-B-5 Leading to the Adoption of IP Method 230/69, J Inst Petr, V. 55, N. 541, pp 36-47, Jan 1969.

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